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FEASIBILITY OF REDUCING PRODUCTION AND DISTRIBUTION COSTS OF MINNESOTA PEAT TO A COMPETITIVE LEVEL

Including

MARKETING & DISTRIBUTION OPPORTUNITIES FOR MINNESOTA PEAT

ECONOMIC DEVELOPMENT ADMINISTRATION
TECHNICAL
ASSISTANCE
PROJECT
U.S. DEPARTMENT OF COMMERCE

STATE OF MINNESOTA

DEPARTMENT OF
IRON RANGE RESOURCES AND REHABILITATION

October, 1968

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Final Report

FEASIBILITY OF REDUCING PRODUCTION AND DISTRIBUTION COSTS OF MINNESOTA PEAT TO A COMPETITIVE LEVEL

for

THE ECONOMIC DEVELOPMENT ADMINISTRATION
UNITED STATES DEPARTMENT OF COMMERCE

Contract No. C-290-65 (Neg.)

"This technical assistance study was accomplished by professional consultants under contract with the Economic Development Administration. The statements, findings, conclusions, recommendations, and other data in this report are solely those of the contractor and do not necessarily reflect the views of the Economic Development Administration."

State of Minnesota
Department of
Iron Range Resources and Rehabilitation
St. Paul, Minnesota 55101

October, 1968

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SUMMARY REPORT

The success of a commercial peat operation depends to a large extent on certain technical information regarding the development of a bog operation, the recovery of the raw material, processing the final product and marketing and distribution practices.

This research project was undertaken primarily to study some of these problems facing peat producers and to make available to them as well as to prospective producers the results of this study.

OBJECTIVES

The principal objectives were to make comprehensive studies of the basic factors relating to production of peat such as ditch spacings, water levels, bog preparation, harvesting and drying techniques, artificial dewatering and etc.

Other objectives were to analyze the conventional production methods and make proposals for alternative production methods. Also a marketing and distribution study for Minnesota produced peat was made.

SCOPE OF STUDIES

Investigations were designed to include the three basic commercial peat types and the comprehensive and large-scale research activities were designed to aid in bog development, harvesting, and production methods. Field and laboratory studies were included and the facilities of the Wilderness Valley Farm, Peat Research Facility, State of Minnesota, the Pine Island bog in Koochiching County and the University of Minnesota, Soil Science labs were utilized.

In addition to the basic peat research, a marketing and distribution study was conducted by the W. B. Saunders Co. and Economic Consultants, Washington, D. C.

Also a comprehensive study was made by a private consultant, R. M. Brower, which included a description of methods, projections of costs and a typical budget for a conventional (field harvest) peat operation for sphagnum moss peat.

EXPERIMENTAL METHODS

Experimental methods used for the field studies on peat included the converging and parallel ditch systems, several networks of wells for the water level studies, pumps for drainage studies, weather instruments for weather studies, clearing and harvesting machinery and equipment, samples for subsurface water contents and bulk density studies, piezometers for water flow studies, plastic greenhouse for accelerated drying and many others.

For the laboratory studies small lab presses for dewatering studies, ovens for water content studies, infrared moisture meter for drying studies, thermometers, cylinders for volumetric determinations (bulk densities), tension tables for simulated peat drying and optimum water studies, small scale models commercial scale and much more equipment made in our shops for a variety of experiments.

RESULTS AND CONCLUSIONS

The results and conclusions of this three-year peat research project may be summarized as follows:

A. Bog clearing and drainage studies.

1. Clearing of vegetation from bogs in Minnesota should be done in winter when peat is frozen.

2. Ditches should also be dug in winter on sphagnum bogs but better in summer on a reed-sedge bog.

3. Preparation of fields for harvesting should lag at least one year behind clearing and ditching in case of a sphagnum peat bog. This is to allow settling and stabilization.

4. In a reed-sedge bog clearing is relatively easy and the ditches should be oriented to take full advantage of the slope of the bog.

5. Isolation of the ditched harvesting fields from flow of water out of undrained bogs is a necessity. This means a good topographic survey should be made prior to location and design of the drainage system.

6. Ditch spacings in reed-sedge peat should be less than 100 feet in width for optimum drainage and drying condition during periods of excessive rainfall.

   On sphagnum bogs research shows that ditches may be spaced slightly over 100 feet apart because these bogs are naturally elevated (raised) above the surrounding bog and are thus easier to drain.

7. On sphagnum moss bogs there is a need to isolate fields by ditching from trash piles left in the clearing operation. However, it is recommended that these piles be burned in spring after clearing and when bog is frozen. Because of fire danger, it must be done before the bog becomes well drained.

8. Fields where ditches are open to adjacent undrained bogs have higher water levels than those isolated by double-ditching.

9. In order to prevent back-up of water in outlet ditches after heavy

rains a gate together with a pump is needed to block water.

10. Narrow vertical ditches (less than 24 inches) were found to be very stable in both reed-sedge and sphagnum peat operations.

11. Harvesting fields should either be slightly crowned (high in middle) or flat between ditches but should never be concave.

12. Research shows that 5-foot depth is sufficient for ditches.

13. Studies show that water tables in deep peat conform to surface of peat. In shallow peat (less than 3 feet) the underlying substrate if five textured (silt and clay) slows drainage and the water tables are higher after rains than those in deep peat.

14. Exhaustive trials have proved that the water levels in the field wells after a heavy rain reflect the true level of the free water in the bog. This level, however, is not the level of the saturated peat. The upper limit of saturation is always below the water table as indicated by the well level. The greater the time between heavy rains the closer the two come together -- free water moving both into the cell structure and out of the bog through ditches.

15. The 75-foot ditch spacings in reed sedge peat were best for maximum drying.

16. Studies in undrained bogs definitely show a need for drainage. They rarely fall below 10 to 12 inches below the surface.

B. Field drying experiments

1. Research shows that the top 1/2 inch of peat dries fastest and should have the capillary union with the underlying peat severed at that depth. Maximum drying occurs when this surface slice is broken into small flat chunks. Finely divided, pulverized peat dries much more slowly than 1/2 inch thick flakes, chips, and crumbs.

2. Studies show that the best drying in upper 1/2 inch occurred in fields where water table levels were 20 or more inches below the surface.

3. In harvesting peat it was found that low humidity, warm and windy days increased drying rate over cloudy and cool days.

4. The data shows that preparation of fields below 1/2 inch depth was not necessary. Only the upper 1/4 to 1/2 inch layer dries effectively. Harvesting equipment should be designed with this fact in mind.

5. A study of temperatures with depth in peat bogs shows that temperatures decrease rapidly below 1 inch level.

6. Sphagnum moss peat dries more rapidly than reed-sedge peat because of lower bulk densities. Water contents of sphagnum moss peat were found to be always less than reed-sedge peat of comparable depth. This is because the water is held less tightly.

7. Since on the average a producer in Minnesota can expect no more than 100 harvest days per year, his field design must result in an operation that will allow maximum use of the 100 and if possible a few extra.

C. Descriptions and basic data of peats

The descriptions and basic data of the peats used in these studies show a wide variation in type of fiber, bulk densities, water storage capacities and degree of decomposition. They are good examples of the commonly occurring peats in the U.S., Canada and Europe.

These basic studies of the physical and chemical properties of Minnesota peats should allow for use of the research findings on harvesting and production of peat here in Minnesota to be applied elsewhere where producers are harvesting similar types of peats and encountering the same problems.

D. Weather data

Rainfall and other weather data for the three years during the course of these investigations was extremely variable. 1965 was very cool and extremely wet in late summer, 1966 was very warm and dry, and 1967 was normal. Collection of data during periods of abnormal as well as periods of normal rainfall and temperature levels evidence to the reliability of the data obtained especially as it pertains to adequacy of fields and ditches, factors related to drying of peat in the field, and ditch spacing for optimum production.

E. Peat-water relationships

1. Water contents of peats from the subsurface to the water table below were found to be related to the depth of the water table below the surface, bulk density of the peat, and the rate of water flow through the peat. Consequently tables were prepared to show these relationships as an aid to peat producers so that they may better understand the water relationships of peat. Water contents are commonly expressed on a percentage wet weight (total weight) basis and are thus very misleading to those in the peat industry as well as to consumers.

2. It was found that water moves very slowly beneath the water table in peat bogs and values of about 10 to 14 inches/day movement were recorded. These rates are similar to those obtained by other investigators elsewhere.

F. Dewatering studies

1. The artificial drying studies show that peats subjected to extremely high temperatures do not readily rewet. The critical temperatures were determined and recommended guidelines were suggested for drying techniques as an aid to peat producers to help them maintain good product quality while remaining in the bounds of economic demands.

2. The use of hydraulic compression to dewater peat was studied extensively using both a lab hydraulic press and a regular commercial press. The results of these studies were encouraging as sufficient water can be removed from the fibrous peats using this technique and the product enjoys the advantage of having a greater dry density and thus a decided freight advantage. Also the high quality of natural peat is retained.

3. A proposal for production of peat using commercial dewatering presses and hydraulic ram balers is included in the final report and the method compared to advantages and disadvantages with the conventional field harvesting method presently being widely used.

G. Conventional harvesting operation

A special report was prepared by a private consultant giving the details of methods, capital investments, projections of costs, and a step by step operation guide and typical budget for a commercial operation utilizing the conventional field harvesting technique for producing peat. This report is included with the final report.

H. Marketing and distribution

Opportunities for Minnesota Peat. This report was prepared by the W. B. Saunders and Co. (Economic Consultants), December, 1965, during the first year of the research project and is included with the final report.

It is a rather comprehensive report concerning the marketing program for a Minnesota-based peat operation. The report includes a detailed examination of present transportation, distribution and marketing practices for domestic and imported peat and evaluates the market which Minnesota producers should consider.

I. OBJECTIVES

A. To determine the basic factors involved in drying peat, especially those related to the quality and type of peat.

   1. Effect of water levels.
   2. Proper ditch spacings.
   3. Bog preparation techniques.
   4. Effect of humidity, temperature, wind, sky cover, etc. on drying rates.

B. To determine the best techniques for drying, harvesting, and processing peat on a commercial scale.

C. To analyze the economic feasibility of harvesting and processing various kinds of peat on a commercial scale.

D. To determine the marketing and distribution opportunities for Minnesota peat and its competitive position.

E. Provide information on peat resources to present producers and prospective producers.

II. SCOPE OF WORK

These studies were designed to aid in bog development, extraction of peat, and processing and distributing Minnesota peat in a commercial operation. The studies considered the following:

A. The principal factors affecting peat harvesting and processing which are related to properties of peat.
B. Efficient methods of field drying.
C. The effect of ditch spacing and water levels on peat drying.
D. The properties of peat related to commercial operations.
E. The best ways to remove roots and wood from peat in harvesting.
F. Study of the marketing and distribution of peat in the United States and the competitive position of Minnesota peat by the W. B. Saunders & Company, Economic Consultants, Washington, D. C.
G. Capital requirements, profit and loss projections, and return on investment for first five years of operation. The study includes the following:

   1. Bog preparation, clearing, ditching, and plant construction costs.
   2. Harvesting costs - methods and recovery techniques.
   3. Material movement systems costs.
   4. Mechanical drying costs.
   5. Baling and bagging methods and costs.
   6. Carloading and warehousing methods and costs.
   7. a. Cost breakdown of plant components.
      b. Cost breakdown of harvesting equipment.
      c. Cost breakdown on operating supplies for volume production.

H. Many other factors which contribute to reducing costs of Minnesota peat and increasing sales are included in the report.

The above problems are common in the peat industry, and development of methods to materially improve drying and harvesting techniques would be very helpful to the industry. No research of this nature has been done in Minnesota, and the industry has resorted to trial and error methods which have limited production. The success of the present peat operations and the future expansion of the industry depends largely on efficient harvesting and processing methods which would greatly improve the quality as well as the quantity of peat produced.

III. FIELD AND LABORATORY STUDIES

A. Study area -- This research project was designed to assist present peat producers located in St. Louis, Carlton, Aitkin, and Itasca Counties as well as others located elsewhere in the state (see Figure 1). The land and facilities of the Wilderness Valley Research Farms, Iron Range Resources and Rehabilitation, at Fens, St. Louis County, Minnesota, were used as well as, State of Minnesota land in Koochiching County. Laboratories for research at both Wildernsss Valley Farms and the University of Minnesota were made available.

B. Experimental methods

1. Development of the Wilderness Valley Farm Peat Research Area

Field History -- Six of the fields originally reclaimed by The Chun King Corporation for peat harvesting were selected for involvement in this study. They are located one mile north of Sax, Minnesota, and East of Highway No. 7, located in the North half of the Northwest Quarter of Section 26 (twp. 55 North, Range 18 West, St. Louis County).

The land was broken in 1956 for agricultural use, but was never farmed. In 1957 it was kept black by disking and abandoned in 1958. Ditches were installed approximately at 150 foot intervals (See Figure 2). The fields were kept black in 1959 and peat was harvested in 1960-62. They were then allowed to revert to the wild bog plants and grasses.

A field road running parallel along the south edge of a large county ditch provides access to all fields across their north ends. The fields are approximately 1/4 mile long and are bounded on the south by a private ditch which empties into the road drainageway paralleling Highway No. 7 and eventually outletting into the Whiteface River.

Figure 1

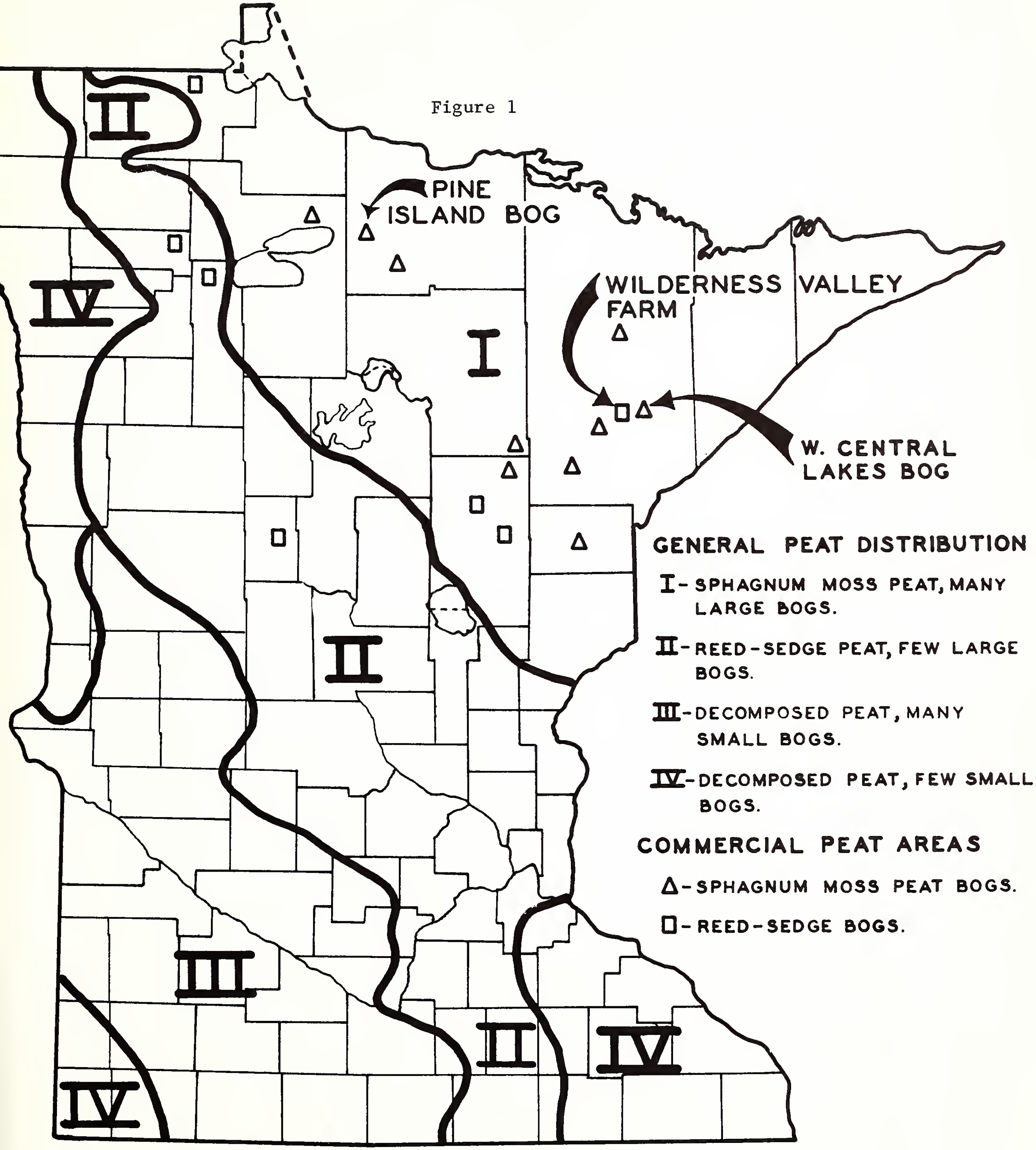
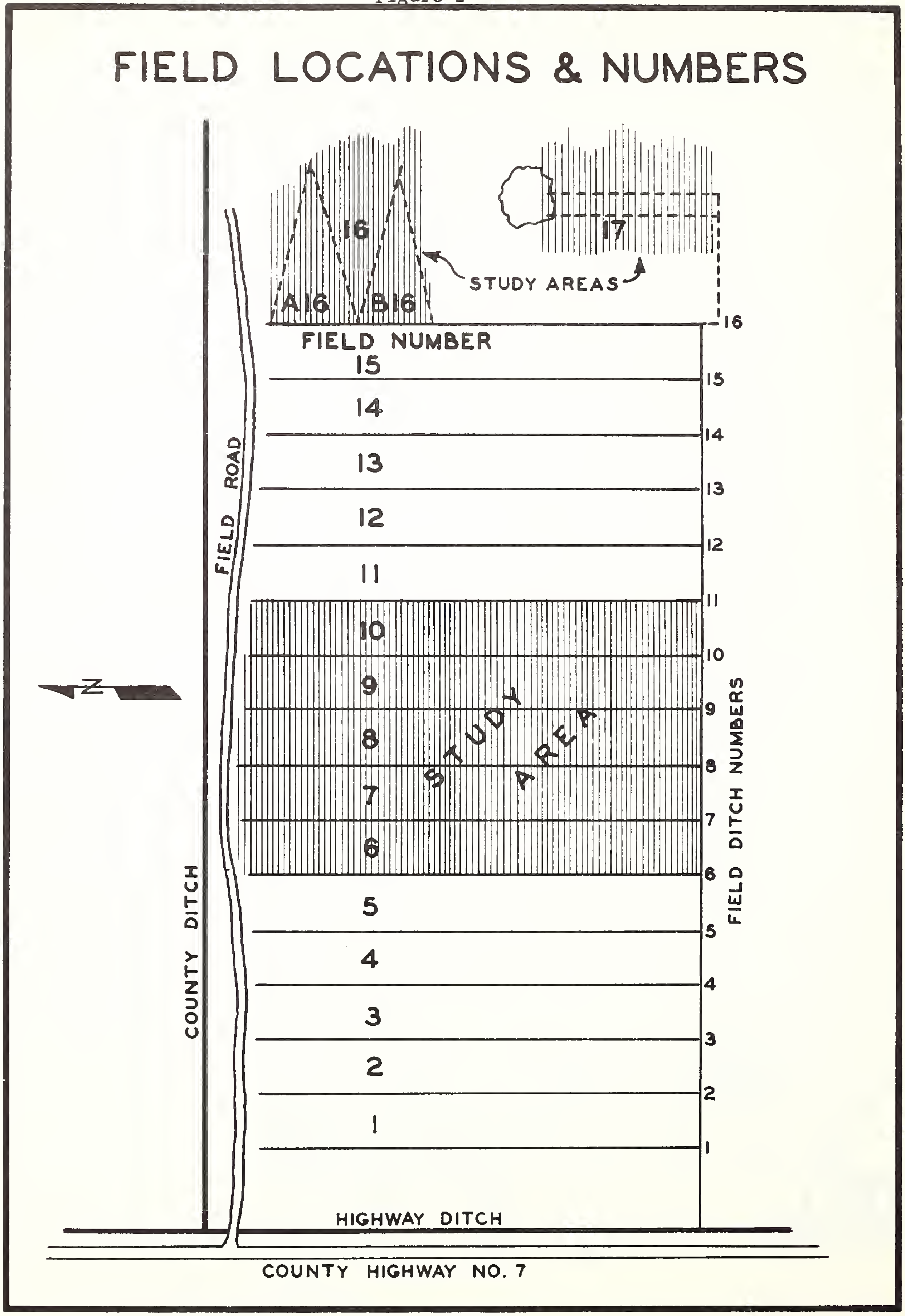

PINE ISLAND BOG
WILDERNESS VALLEY FARM
W. CENTRAL LAKES BOG
I
II
II
II
III
IV
IV
IV
GENERAL PEAT DISTRIBUTION
I - SPHAGNUM MOSS PEAT, MANY LARGE BOGS.
II - REED-SEDGE PEAT, FEW LARGE BOGS.
III - DECOMPOSED PEAT, MANY SMALL BOGS.
IV - DECOMPOSED PEAT, FEW SMALL BOGS.
COMMERCIAL PEAT AREAS
Δ - SPHAGNUM MOSS PEAT BOGS.
□ - REED-SEDGE BOGS.

Figure 2


FIELD LOCATIONS & NUMBERS
16
A16
B16
17
STUDY AREAS
FIELD NUMBER
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
STUDY AREA
FIELD ROAD
COUNTY DITCH
N
FIELD DITCH NUMBERS
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
HIGHWAY DITCH
COUNTY HIGHWAY NO. 7

The field depth of the peat averages between 4 and 5½ feet. The uniformity of peat quality is good, being only slightly decomposed and with a moderate amount of sticks.

Field Development in 1965 -- On July 1, 1965, fields 6 through 10 were earmarked for study. These fields had the best ditches and had lost very little peat to previous harvest seasons. All of them supported an accumulation of dead "hay" and the new growing plants of the current season. Since the methods of restoring each field to a harvestable surface varied, the fields will be described individually.

Field No. 6 (See Figure 3) -- This field was first "edged" with a D-2 caterpillar dozer. The blade was dropped over the soddy ridges that had been built up in past seasons through the inability to harvest completely to the ditches. The ditches had been put in with a dragline and are straight edged and four feet wide. After this soddy edging was pulled back and fanned out over the center third of the field, it was disked with a tandem disk. The field was then plowed with a 24-inch breaker plow to a depth of 12 inches. The west half of the plowing was then double-disked with an Athens heavy duty brush and bog harrow, the last half double disked with a John Deere conventional, tandem field disk.

Field No. 7 -- This field was first "chopped" with a Lundell forage harvester, the dead and green grass mixture being collected in a large peat harvesting wagon towed behind the harvester. Many, many loads of waste were hauled off and dumped in a long pile between the east-west county ditch and the field road at the north end of Field No. 10. It was then "edged" with the D-2 as on Field No. 6, but the edgings were dozed into piles and then hauled from the field with a front end crawler-loader and the peat wagons. The field was then staked for ditching so as to make two fields, one 75 feet wide and the other 60. The other 80 ditch castings were dragged back to the center third of the east half (designated 7-E) and both fields were turned with a 16-inch 2-bottom plow to a depth of 6 inches. Both sides were then double disked with the tandem field disk. Several loads of sticks and roots were picked from this field. One line of "wells" was installed running across the center of 7-E, east to west. The wells and new ditch are described fully in paragraphs dealing separately with these two subjects (See Figure 4) for other field data).

Field No. 8 -- This field was cleared of the top growth as discussed under Field No. 7 and similarly edged. Then the two outside thirds (eventually identified as 8W and 8E) were scalped with the Lundell. The flails were set to skin the surface of the field to a depth of about one-half inch, removing nearly all of the grass crowns and leaving a smooth, plant-free

Figure 3

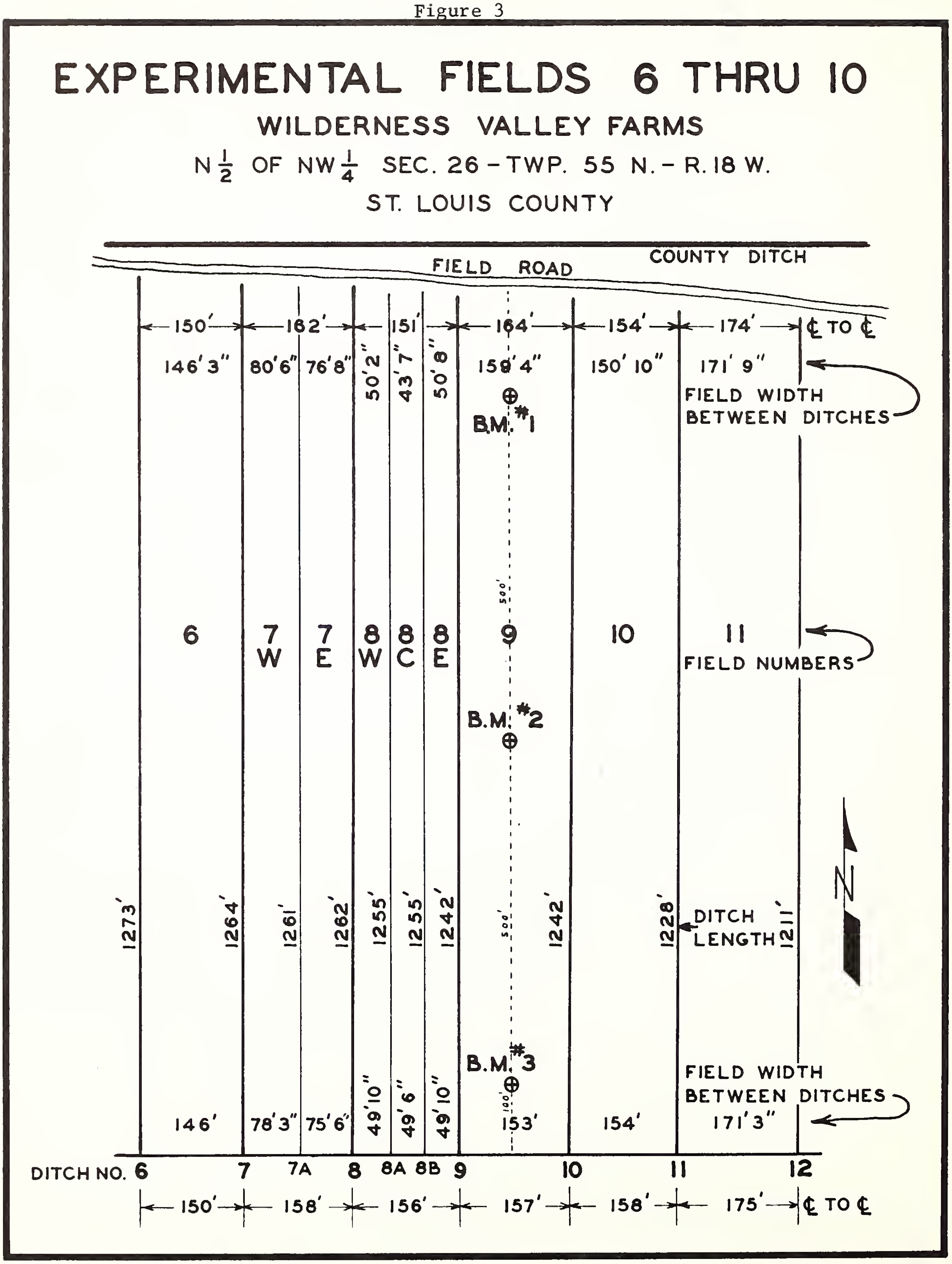
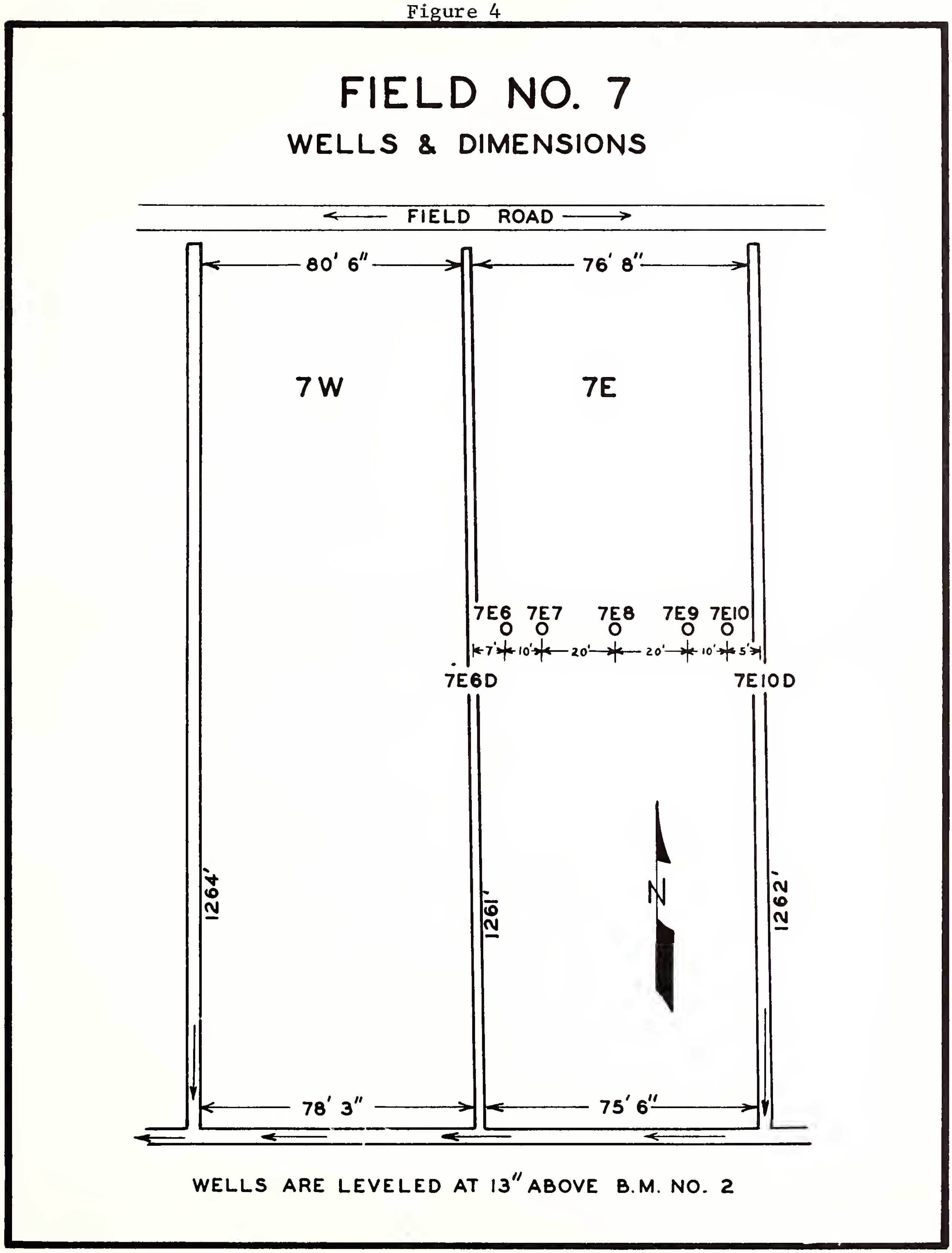
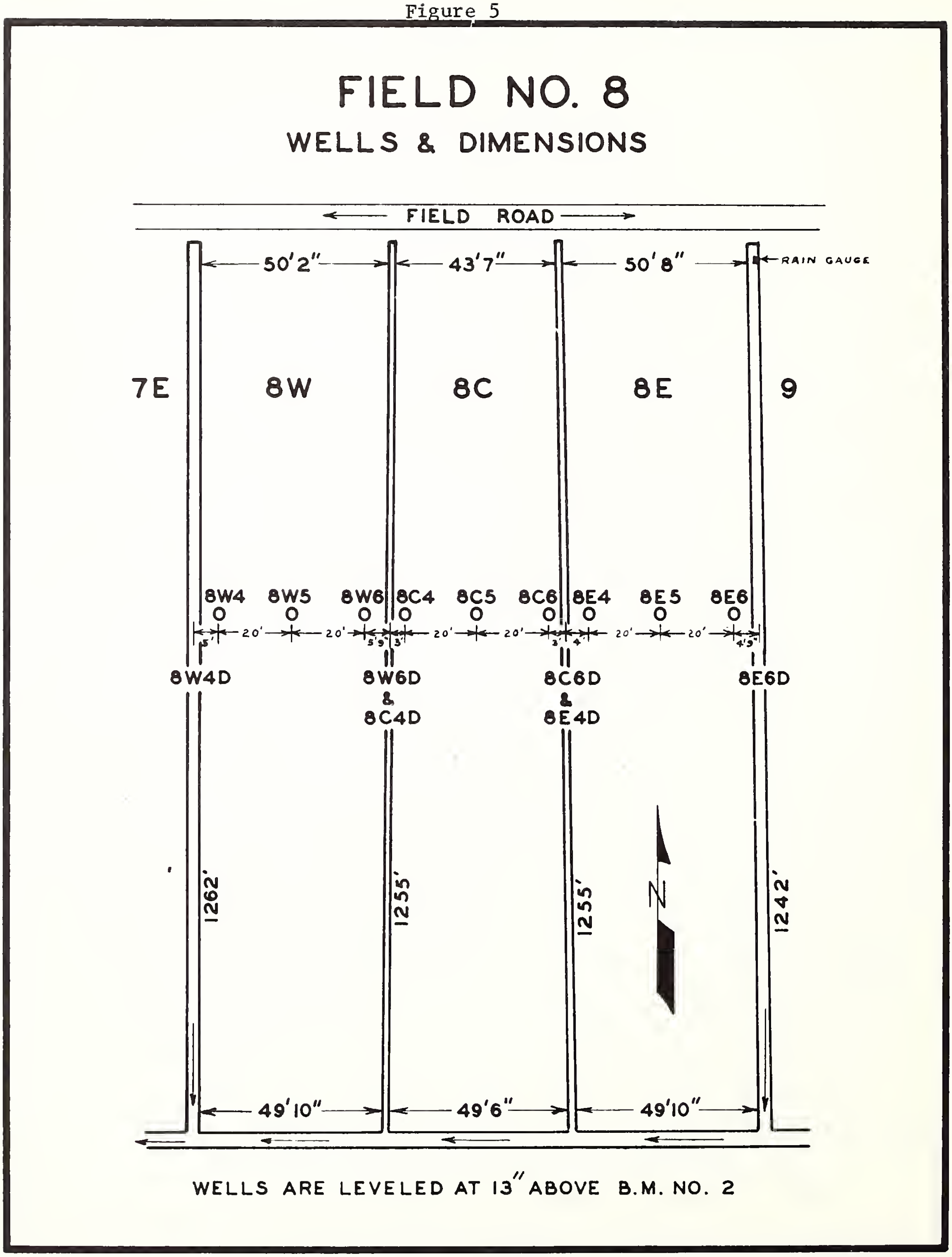

EXPERIMENTAL FIELDS 6 THRU 10
WILDERNESS VALLEY FARMS
N 1/2 OF NW 1/4 SEC. 26 - TWP. 55 N. - R. 18 W.
ST. LOUIS COUNTY
COUNTY DITCH
FIELD ROAD
150'
162'
151'
164'
154'
174'
℄ TO ℄
146'3"
80'6"
76'8"
50'2"
43'7"
50'8"
159'4"
150'10"
171'9"
FIELD WIDTH BETWEEN DITCHES
B.M. #1
500'
6
7 W
7 E
8 W
8 C
8 E
9
10
11
FIELD NUMBERS
B.M. #2
N
1273'
1264'
1261'
1262'
1255'
1255'
1242'
500'
1242'
1228'
DITCH LENGTH
1211'
B.M. #3
100'
FIELD WIDTH BETWEEN DITCHES
146'
78'3"
75'6"
49'10"
49'6"
49'10"
153'
154'
171'3"
DITCH NO. 6
7
7A
8
8A
8B
9
10
11
12
150'
158'
156'
157'
158'
175'
℄ TO ℄

Figure 4



WELLS ARE LEVELED AT 13" ABOVE B.M. NO. 2

Figure 5


FIELD NO. 8
WELLS & DIMENSIONS
FIELD ROAD
50'2"
43'7"
50'8"
RAIN GAUGE
7E
8W
8C
8E
9
8W4
8W5
8W6
8C4
8C5
8C6
8E4
8E5
8E6
5'
20'
20'
5'9"
3'
20'
20'
3'
4'
20'
20'
4'9"
8W4D
8W6D & 8C4D
8C6D & 8E4D
8E6D
1262'
1255'
1255'
1242'
N
49'10"
49'6"
49'10"
WELLS ARE LEVELED AT 13" ABOVE B.M. NO. 2

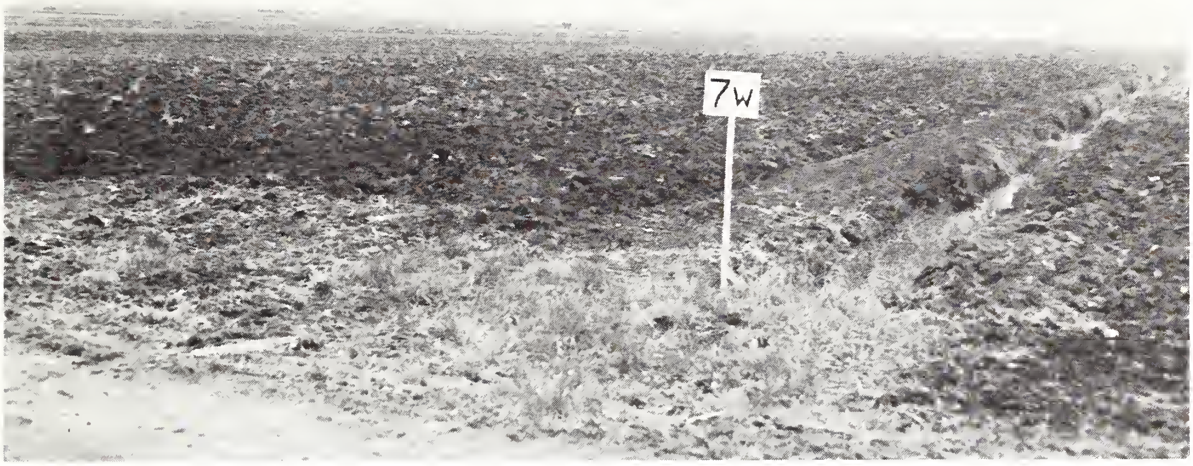


Fig. 6. Field 7W prepared.

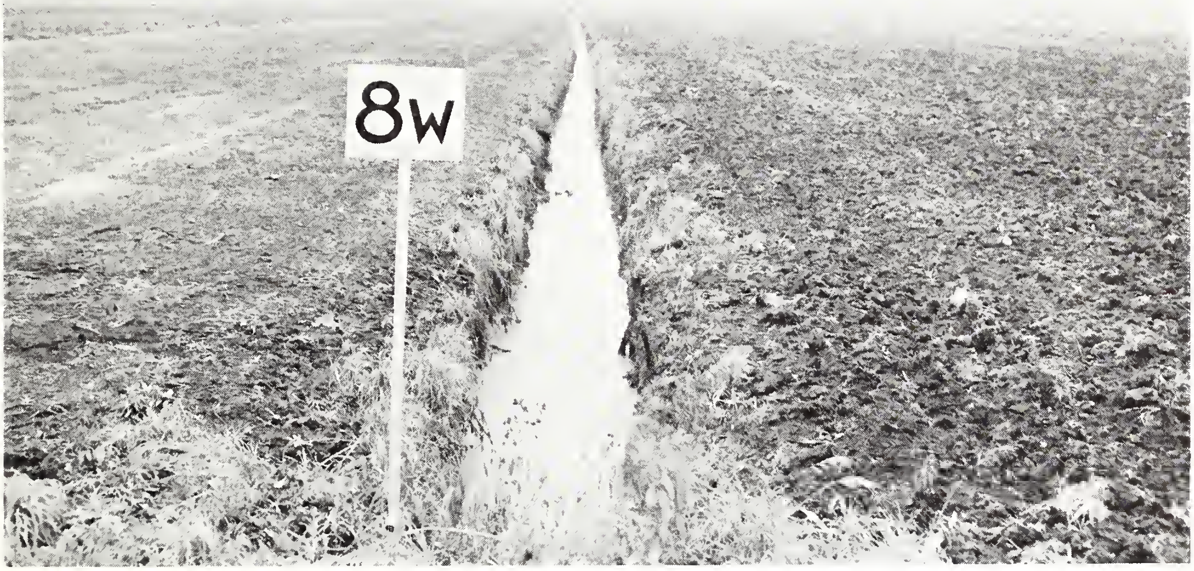


Fig. 7. Field 8W - Old ditch.

surface. The area was then staked to provide two fields about 50 feet wide and the center (8C) comprising the remainder of the total width (See Figure 5 for exact measurements). The ditch castings fell on 8E and 8C and were dozed back to the center of each to provide a noticeable crown to the strip. The center field was then plowed to the depth of 6 inches and double disked. The flanking fields were both harrowed with a spike tooth drag and then gone over several times with an Eversman land leveler. They were then reharrowed and packed with a field roller. Sticks were picked from all three fields.

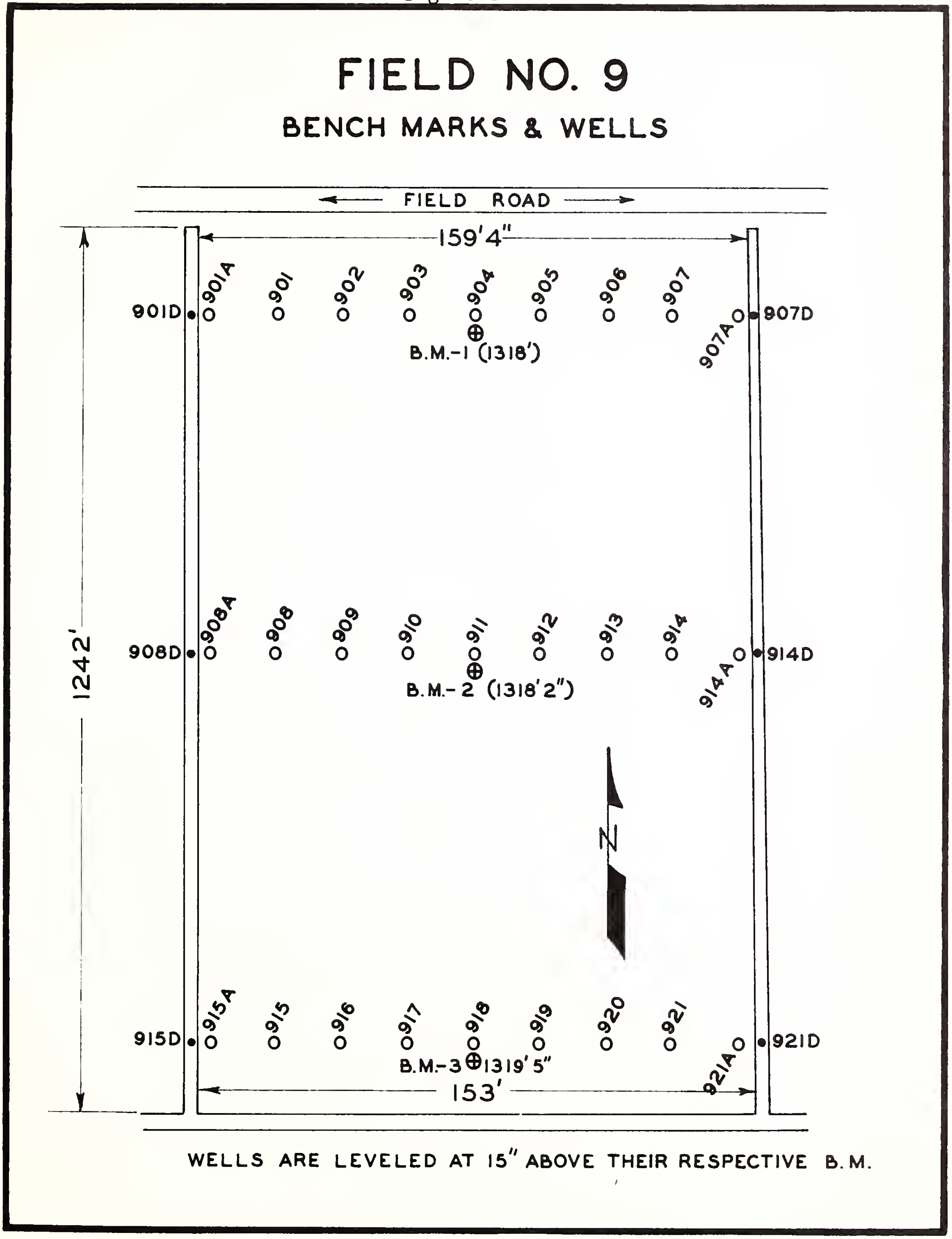
Wells were placed across the centers of all three fields (See Figure 5).

Field No. 9 -- This field was chopped close and edged as described under Field No. 7. It was then double disked with the Athens brush and bog harrow, followed with several field diskings. The spike tooth drag, rotary hoe, field roller and land leveler were used sequentially to provide a smooth, firm level surface. Sticks and grassy tufts were scratched into windrows twice with a John Deere side rake and picked up with the forage chopper and wagon for removal from the field. The field was in prime condition for early spring harvesting studies to involve a variety of soil disturbing techniques. Three bench marks were established at points noted on Figure 8. They are 7-foot lengths of $1\frac{1}{2}$ inch boiler tubing with a 4-inch by 4-inch plate welded on one end bearing a number embossed with welding rod. The marker is driven deeply into the silty substrate, with the top end buried about 10 inches below the surface. A short section of 4 inch aluminum irrigation pipe provides ready access to the bench mark. A row of wells is located at each bench mark. Bench Mark No. 3 is located 100 feet north of the south ditch and the next two follow in 500 foot spacings.

Field No. 10 -- This field was chopped and edged as with Field No. 7 and a harvesting surface developed only with the field disk, spike harrow and rotary hoe. It was side raked twice for root and tuft removal in the manner discussed with Field No. 9. It is the widest field in the comparison. It was partially leveled with the Eversman in 1965 and completed in early 1966.

Ditching -- The original ditching of these fields, done by The Chun King Corporation, was accomplished with a dragline which left straightsided, four-foot wide structures. They were in good shape with exception of a considerable accumulation of sludge and grass in some. The worst of these

Figure 8


FIELD NO. 9
BENCH MARKS & WELLS
FIELD ROAD
159'4"
1242'
153'
901D
901A
901
902
903
904
905
906
907
907A
907D
B.M.-1 (1318')
908D
908A
908
909
910
911
912
913
914
914A
914D
B.M.-2 (1318'2")
N
915D
915A
915
916
917
918
919
920
921
921A
921D
B.M.-3 1319'5"
WELLS ARE LEVELED AT 15" ABOVE THEIR RESPECTIVE B.M.

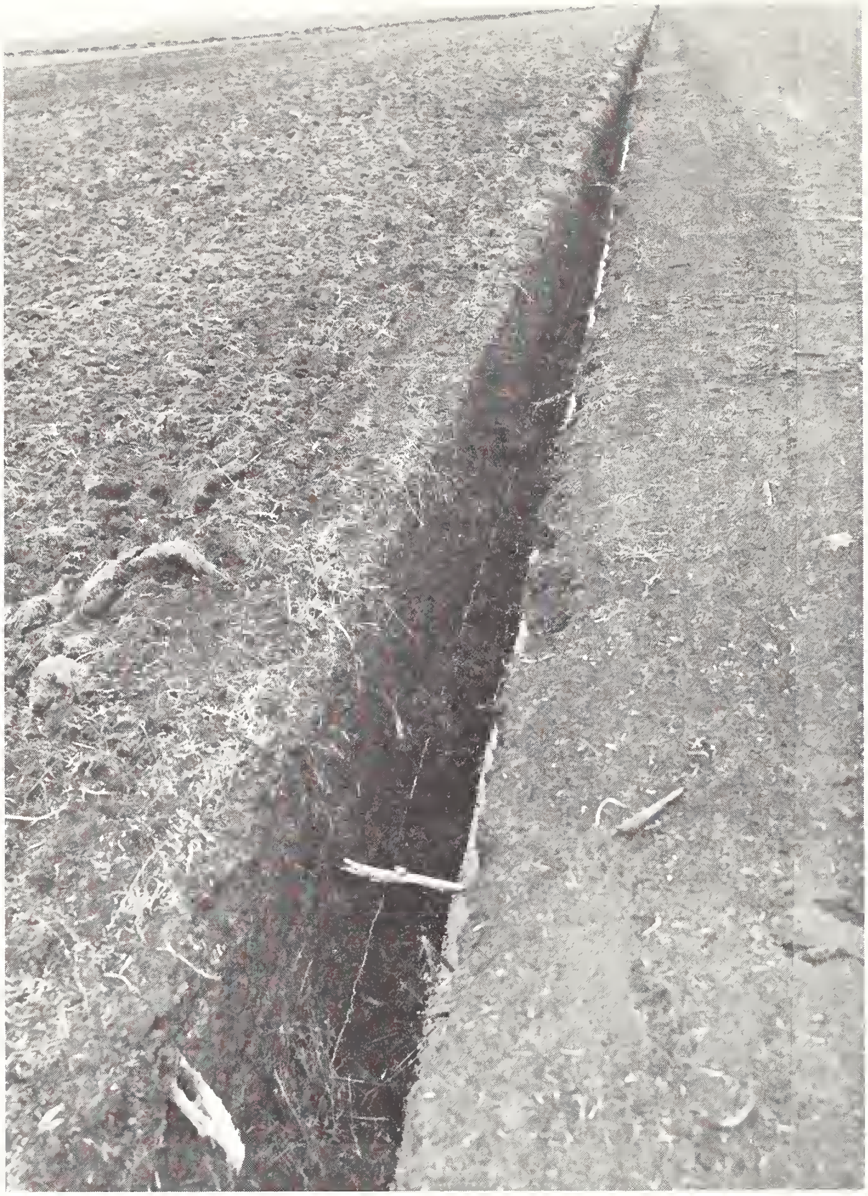


Fig. 9. The above ditch was excavated with a Parson Bucket Trencher (Model 200). It is 18 inches wide and goes the full depth of the peat which averaged 5 feet. Sticks left hanging from the walls give evidence of the low wood content of this peat.

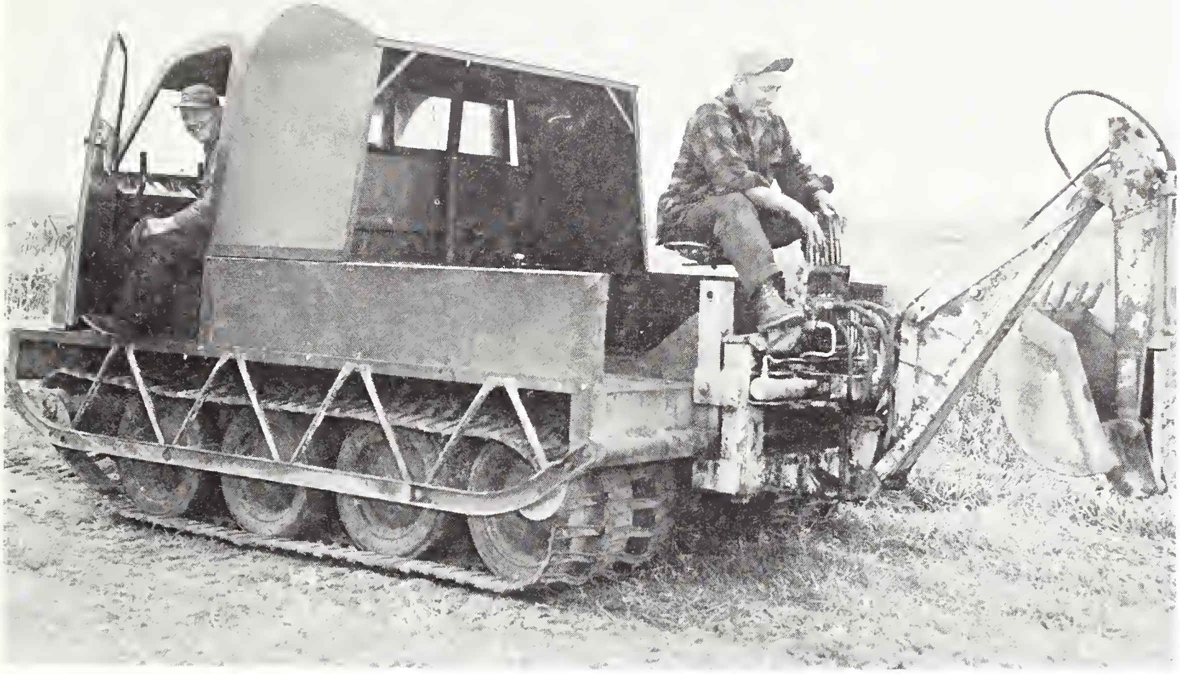


Fig. 10. The Bombardier ("Muskeg Carrier" S-61) pictured above and carrying a Davis D-100 Backhoe was used extensively in the cleaning of old ditches and the construction of new ones.

were sluiced out with an open-mouthed, fifty-five gallon drum being dragged along the ditch and the thickest of the slurry hauled off the field. The main ditch across the south ends of the field was cleaned out with the Bombardier backhoe, owned by the Mineral Research Division of the Department of Iron Range Resources and Rehabilitation who provided the crew for the job. They cleaned the ditch extending from Highway No. 7 east to Field Area No. 17 (See Figure 10) a distance of about 3,700 feet; this ditch had many spots where the field outlets were plugged with refuse. A contract was negotiated with Francis Byrns of Zim, Minnesota, to install three ditches as staked out in Field Nos. 7 and 8, totalling 3,771 feet. He used a Parson 200 model bucket-trencher, excavating a ditch 18 inches wide to the bottom of the peat, leaving straight-sided walls. The peat averaged 4½ to 5½ feet deep. Each ditch was begun at the south end of the field and the castings delivered to the right of the machine. As noted elsewhere, the berm was spread with a dozer and disked dragged and rotary-hoed into a gentle crowning of fields (8E, 8C and 7E).

Laying Out Research Areas -- The primary object in each field prepared was to provide a smooth clean surface in several degrees of density from which to collect field data. This was done leaving the following surface conditions:

Firm and undisturbed (8W)
Loose 2" disking (10)
Firm 3" disking (9)
Loose 6" plowing (8C, 7E and W)
Firm 2" disking (8E)
Loose 12" plowing (6)

In addition, field widths of approximately 45, 50, 75, 80, 150, 160, and 170 feet between ditches can be related to various surface handling techniques.

To gather data showing the relationship to ditch spacing and water loss in the soil profiles a system of wells was installed in Field Nos. 7E, 8W, 8C, 8E, and 9, and Field Areas 16 and 17.

Wells in Harvest Fields -- Field No. 9 -- To determine the water table profile as it relates to rainfall, ditch spacing, capillarity and soil surface condition, a series of "wells" were inserted at the three bench marks. One and one-quarter inch aluminum irrigation pipe was cut to 6-foot lengths with 1/4 inch holes bored in random spiral up the pipe from the bottom to near the expected depth of the soil. The bottom end was pinched shut to prevent the pipe filling with peat when shoved into the soil. The wells were located at 20-

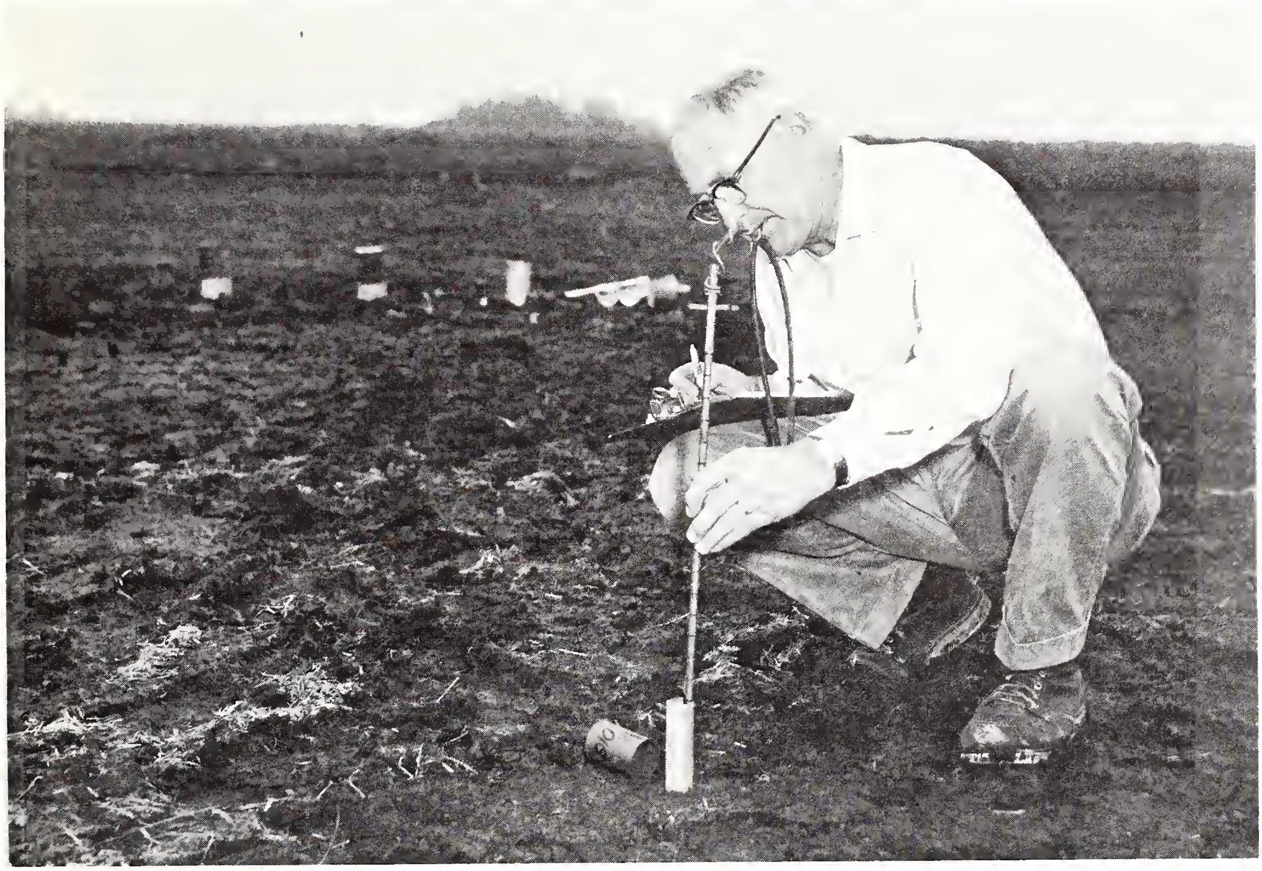
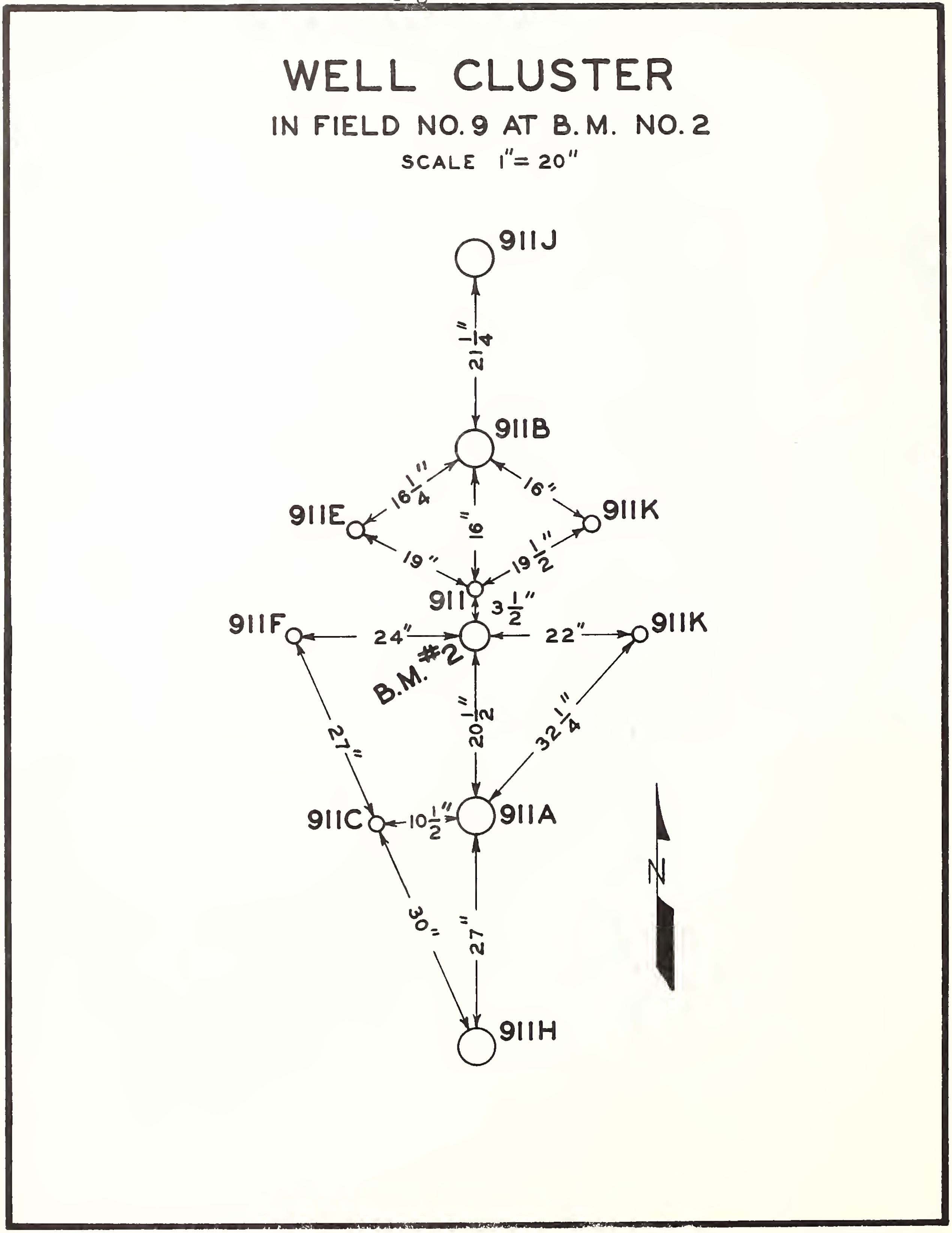


Fig. 11. "Bubbling" a well to determine water level. A 48 ft. copper tube marked at 1 inch intervals and fitted with a mouth piece of rubber tubing is inserted into the well and air is gently blown through it. A sound of bubbling indicates the water surface has been reached and a reading is made directly from the graduations marked on the tube and read at the top edge of the well.

Figure 12


WELL CLUSTER
IN FIELD NO. 9 AT B. M. NO. 2
SCALE 1" = 20"
911J
21 1/4"
911B
16 1/4"
16"
16"
911E
911K
19"
19 1/2"
911
3 1/2"
911F
24"
B.M. #2
22"
911K
27"
20 1/2"
32 1/4"
911C
10 1/2"
911A
N
30"
27"
911H

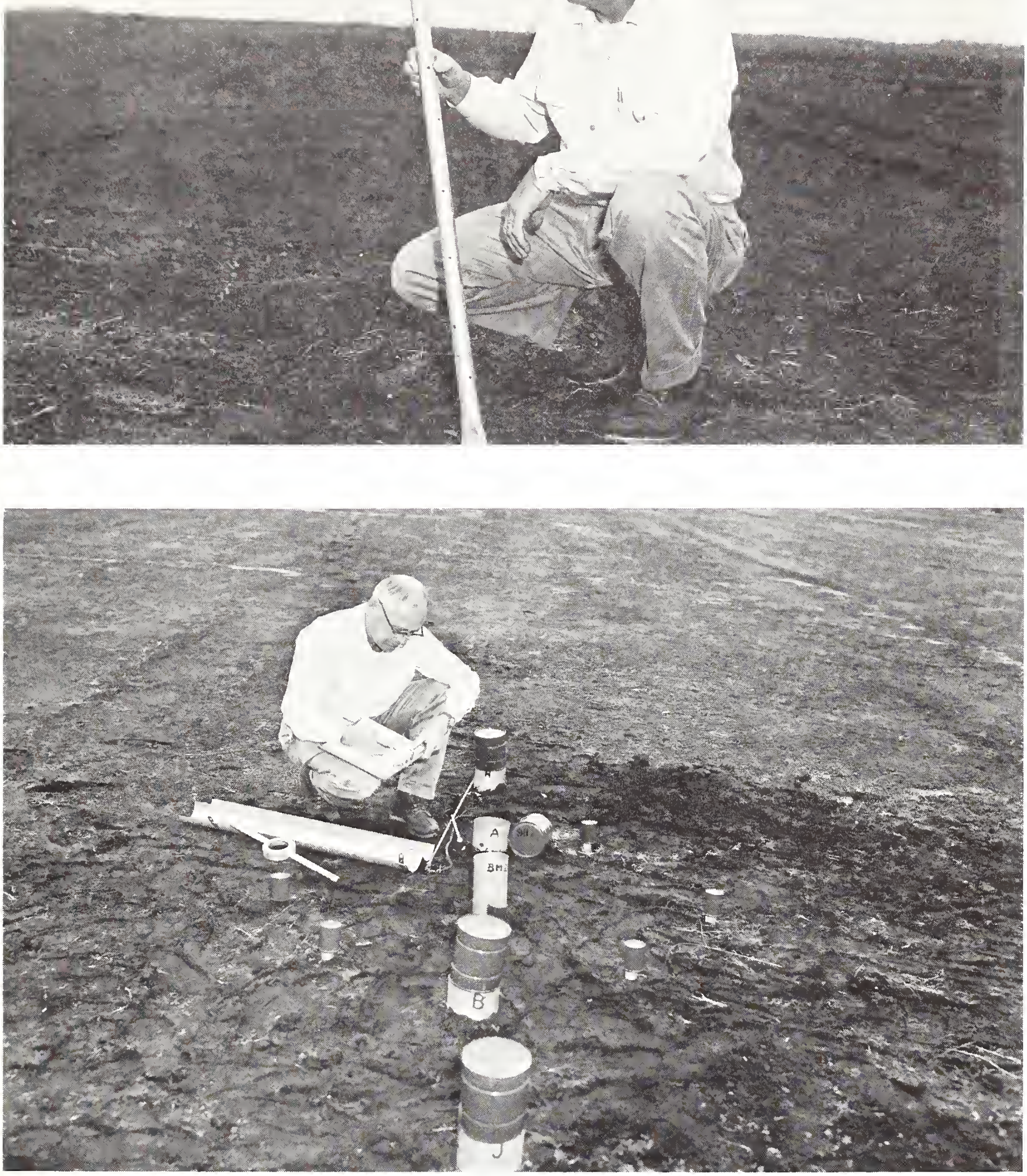


Fig. 13. Above - One of wells.
Below - Well cluster in Field 9.

foot intervals east and west from the bench marks with the last well on either end being set 2 feet from the ditch. Boiler pipe markers were set in the ditch proper to have a fixed point from which to measure the water level in the ditches. After setting the wells they were leveled in with a transit at a point 15 inches above the respective bench marks.

At bench mark No. 2 a cluster of wells of various sizes and lengths were put in to determine the reliability of this system and attempt to relate the readings to the moisture percentage of the adjacent peat. The location and identification of this cluster is diagrammed in Figure 12. The wells are described as follows:

911A - A 5" aluminum pipe with open end, pushed through the peat and 11" into the substrate.

911B - A 5" aluminum pipe with closed bottom, but perforated sides, dug 7" into the substrate.

911C - A $1\frac{1}{4}$" perforated pipe with closed end driven 10" into the substrate.

911E - A $1\frac{1}{4}$" perforated, closed bottom pipe set 24" into the peat.

911F - A $1\frac{1}{4}$" non-perforated pipe with an open bottom set 24" into the peat.

911G - A $1\frac{1}{4}$" aluminum pipe with closed walls and open bottom set 41" into the peat.

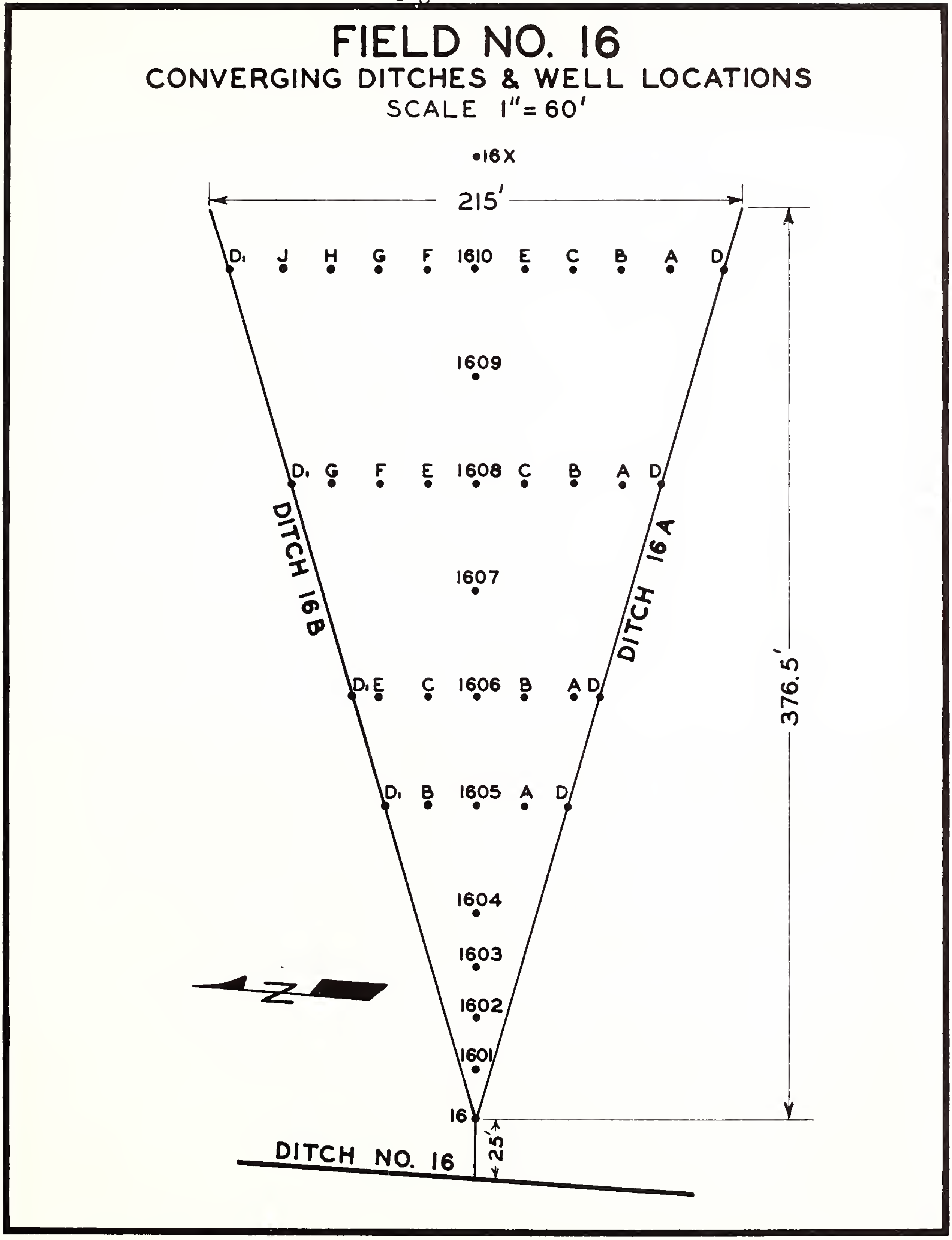
911H - A 5" pipe with perforated walls and closed bottom set 24" into the peat.

911J - A 5" pipe with closed walls and open bottom set 24" into the peat.

911K - A $1\frac{1}{4}$" perforated aluminum pipe set 41" into the peat (closed end).

Wells in the Harvest Fields -- Field No. 8 -- Three wells were placed directly west of bench mark No. 2 (Field No. 9) in each of the three narrow plots 8E, 8C, and 8W, with the middle well located at the center of each and two 20 feet both sides of center. Again the ditches were "staked" to provide a bearing from which to measure the water level in them. All of these wells were leveled in at 13 inches above bench mark No. 2 in Field No. 9.

Figure 14



FIELD NO. 16

CONVERGING DITCHES & WELL LOCATIONS

SCALE 1" = 60'

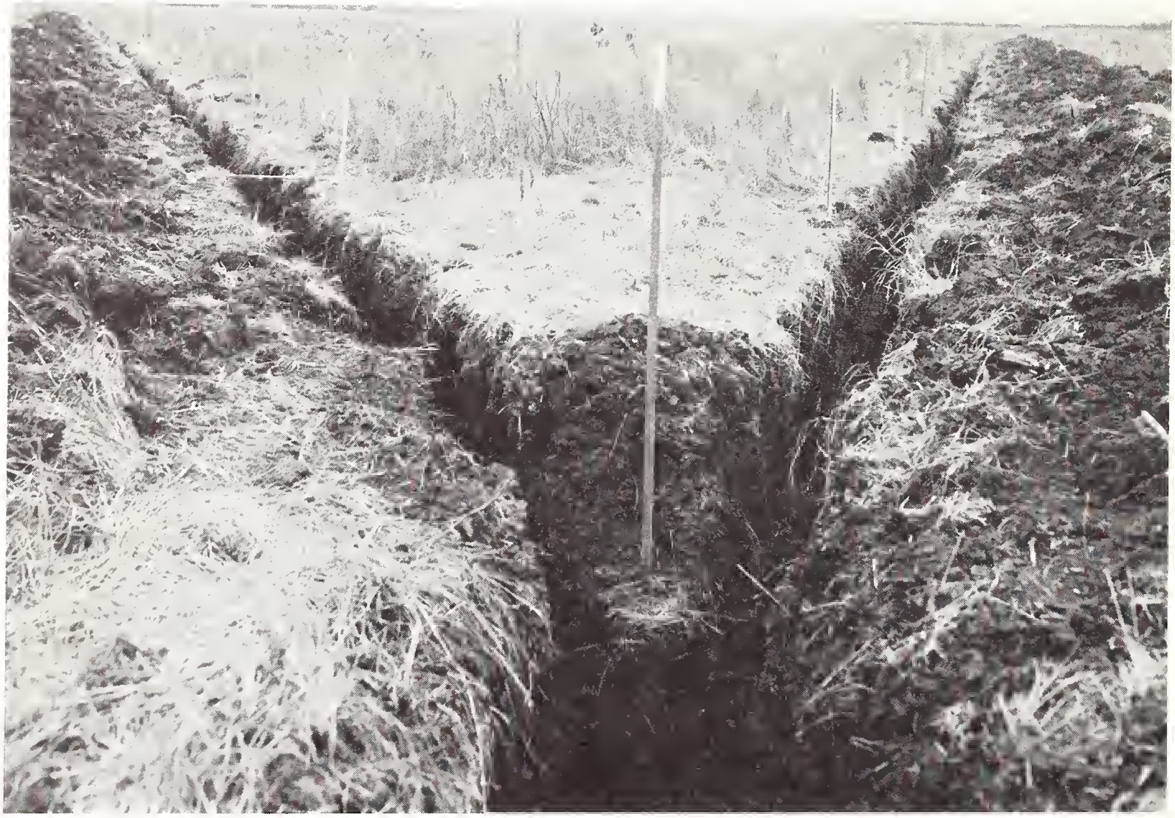
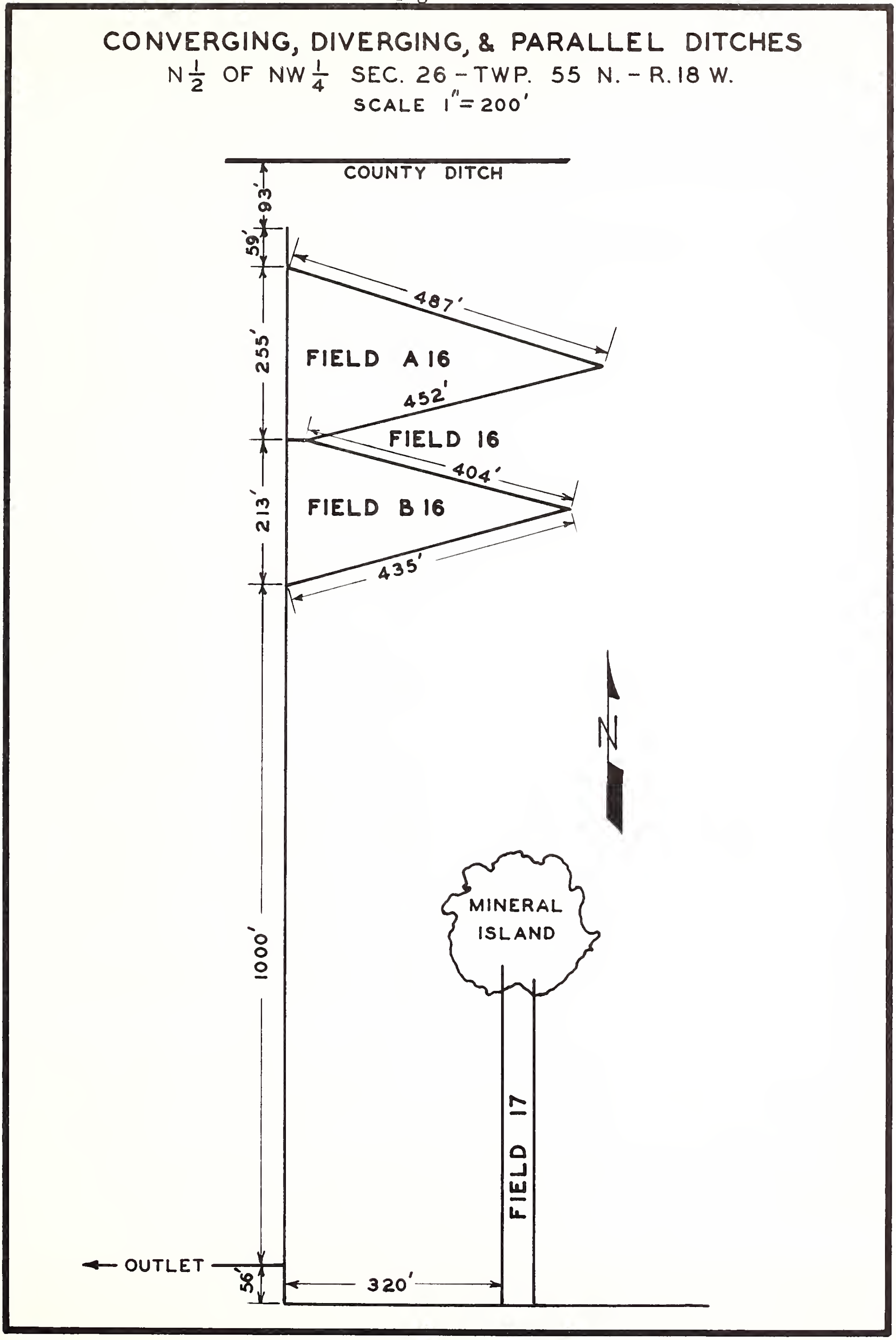


Fig. 15. The view above shows the west end of Field 16 (the east ends of A 16 and B 16 would be almost identical in appearance). The ditches are roughly 20 inches wide and are about $5\frac{1}{2}$ feet deep. The were dug with the Bombardier.

Figure 16


CONVERGING, DIVERGING, & PARALLEL DITCHES
N 1/2 OF NW 1/4 SEC. 26 - TWP. 55 N. - R. 18 W.
SCALE 1" = 200'
COUNTY DITCH
93'
59'
487'
255'
FIELD A 16
452'
FIELD 16
404'
213'
FIELD B 16
435'
N
MINERAL ISLAND
1000'
FIELD 17
OUTLET
56'
320'

Wells in Harvest Fields -- Field No. 7E -- Five wells were placed across the center of this field as noted in Figure 4 and at the same level.

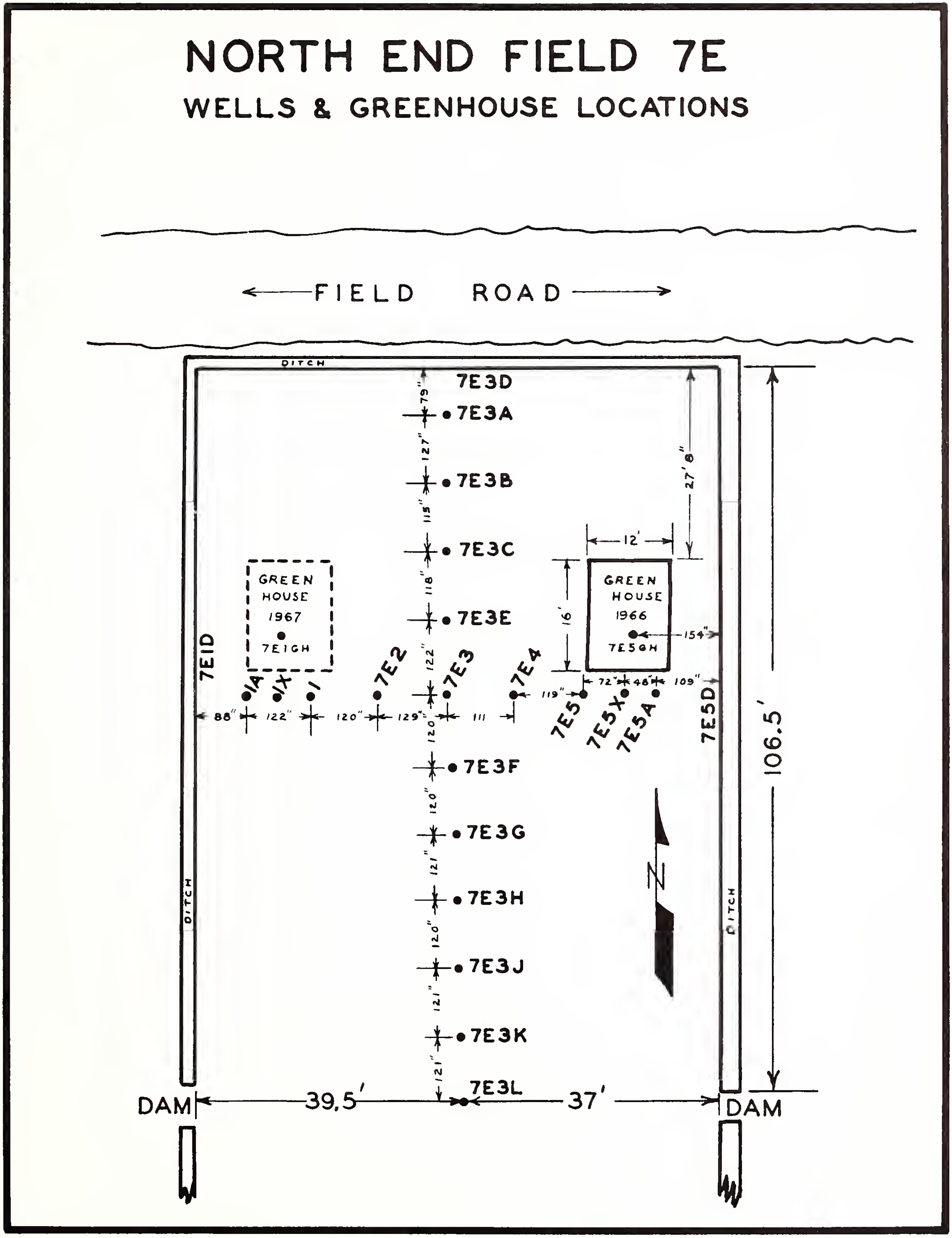
Wells in the Harvest Fields -- Field No. 16 -- Permission was secured from The Chun King Corporation to establish some purely experimental ditch systems on land of theirs adjoining the most easterly of the old harvest fields (See Figure 2). The I.R.R. & R. Bombardier backhoe crew dug a "Y" system involving a short stem outlet that permits a single bridge access to Field Area 17. The arms of the "Y" extend roughly 400 feet from the stem and spread a bit over 200 feet apart at their extreme ends (Figure 16). The ditches are straightsided through the depth of the peat, averaging 5½ feet and are about 20" wide. At measured intervals wells, as previously described were set and leveled (See Figure 14). They are so located as to give comparative readings at 10 different ditch spacings (12½ to 200 feet) and four different detailed profiles at 75, 100, 150, and 200 feet. (830 feet of ditching was done at this point.) Chart 1 gives the peat depth at a variety of stations on this field. See page for discussion of expansion of this area.

PEAT DEPTH
Field No. 16

Station No.	Depth	Station No.	Depth	Station No.	Depth
16	5' 9"	1604	5' 6"	1608D	5' 6"
1601D	5' 0"	1604D	5' 6"	1608	5' 10"
1601	5' 10"	1605D	5' 6"	1608D$_1$	5' 6"
1601D$_1$	5' 10"	1605	5' 6"	1609D	5' 6"
1602D	5' 6"	1605D$_1$	6' 0"	1609	5' 6"
1602	5' 6"	1606D	5' 0"	1609D$_1$	5' 2"
1602D$_1$	5' 6"	1606	5' 6"	1610D	5' 3"
1603D	5' 6"	1606D$_1$	5' 6"	1610	5' 10"
1603	5' 9"	1607D	5' 6"	1610D$_1$	5' 0"
1603D$_1$	5' 0"	1607	5' 10"	16B	5' 0"
1604D	5' 4"	1607D$_1$	5' 6"	16A	5' 10"

Wells in Harvest Fields -- Field Area No. 17 -- Several hundred feet further south of Area No. 16 on the same Chun King property (NW¼ of NE¼, Section 26, Twp. 55N, R. 55W, St.Louis County) a small mineral island rises to the surface of the peat. Two parallel ditches were dug (by I.R.R. & R. Bombardier crew) roughly 50 feet apart from the mineral island south to the main east-west ditch. The area supports well at 25 foot intervals from the minimum peat to maximum to study the rate of water movement in peats of varying depth and to determine the effects of a sloping "floor" under the peat body (See Figures 2 and 16)

Figure 17


NORTH END FIELD 7E
WELLS & GREENHOUSE LOCATIONS
FIELD ROAD
DITCH
7E3D
79"
7E3A
127"
7E3B
115"
7E3C
118"
7E3E
122"
120"
7E3F
120"
7E3G
121"
7E3H
120"
7E3J
121"
7E3K
121"
7E3L
27'8"
12'
16'
GREEN HOUSE 1967
7E1GH
GREEN HOUSE 1966
7E5GH
154"
7E1D
1A
1X
1
7E2
7E3
7E4
88"
122"
120"
129"
111
119"
72"
48"
109"
7E5
7E5X
7E5A
7E5D
106.5'
N
DAM
39.5'
37'
DAM

(982 feet of ditch was dug for this field area.)

Controlled Water Level System -- Field 7E -- Late in August, 1966, a plan to induce the raising and lowering of the water level in a field was put into effect. The northern-most end of Field No. 7E was chosen. The north-south ditches on both sides of the field were connected by a ditch across the north end of the field 18 inches wide and dug to the bottom of the peat (about 5 feet). Each of the side ditches was blocked at a point approximately 100 feet south of the north field corners by a dam. The dams were constructed of two walls of old railroad ties trenched across the ditches so as to hold a block of peat 4 feet "long" in the east ditch (which was wider and easier to work in, assuring good tramping of the fill from top to bottom) and 8 feet long in the narrow (18 inches) west ditch. Before the cribs were filled with peat a sheet 6 mil, poly film was embedded against the inside of both crib walls. The dams were set into the firm ditch bottoms, 8 inches below the sludge. No seepage could be detected through the dams either at high or low water levels.

In August, 1967, these dams proved to have been damaged by frost or crayfish and had to be repaired. This was done by hand digging a trench 2 feet wide and 6 feet long and 5 feet deep through the center of each dam (at right angles to the ditch) and filling it with a mineral soil core.

Figure 17 diagrams the field layout showing the well positions and their identifying numbers. They were set at 10-foot intervals across the field and at the same intervals on an approximate center line north and south. All of the wells, including stakes set at the 3 ditch points, were leveled at a common height.

Expansion of Converging Ditch System -- Additions to the "Y" or converging ditch system (Field No. 16) were made late in the fall of 1966 and in early spring of 1967. Field A16 lies adjacent to 16 on the north (See Figure 18) and is known as the "diverging ditch system". It was constructed to determine whether or not the converging system was being influenced by a lateral influx of ground water through the open end of the "funnel shaped" field from the adjacent raw bog. A similar though smaller field lies next to the south side of Field No. 16 and it is designated "B-16". It duplicates A-16 from the 175 foot ditch width on down. A portion of this system was denuded in late 1967 as a check against the effect of green cover on water loss. There are many questions related to the degree of water loss through photosyntheses and transpiration that are yet unanswered. The well placements and identifications for Fields A-16 and B-

Figure 18

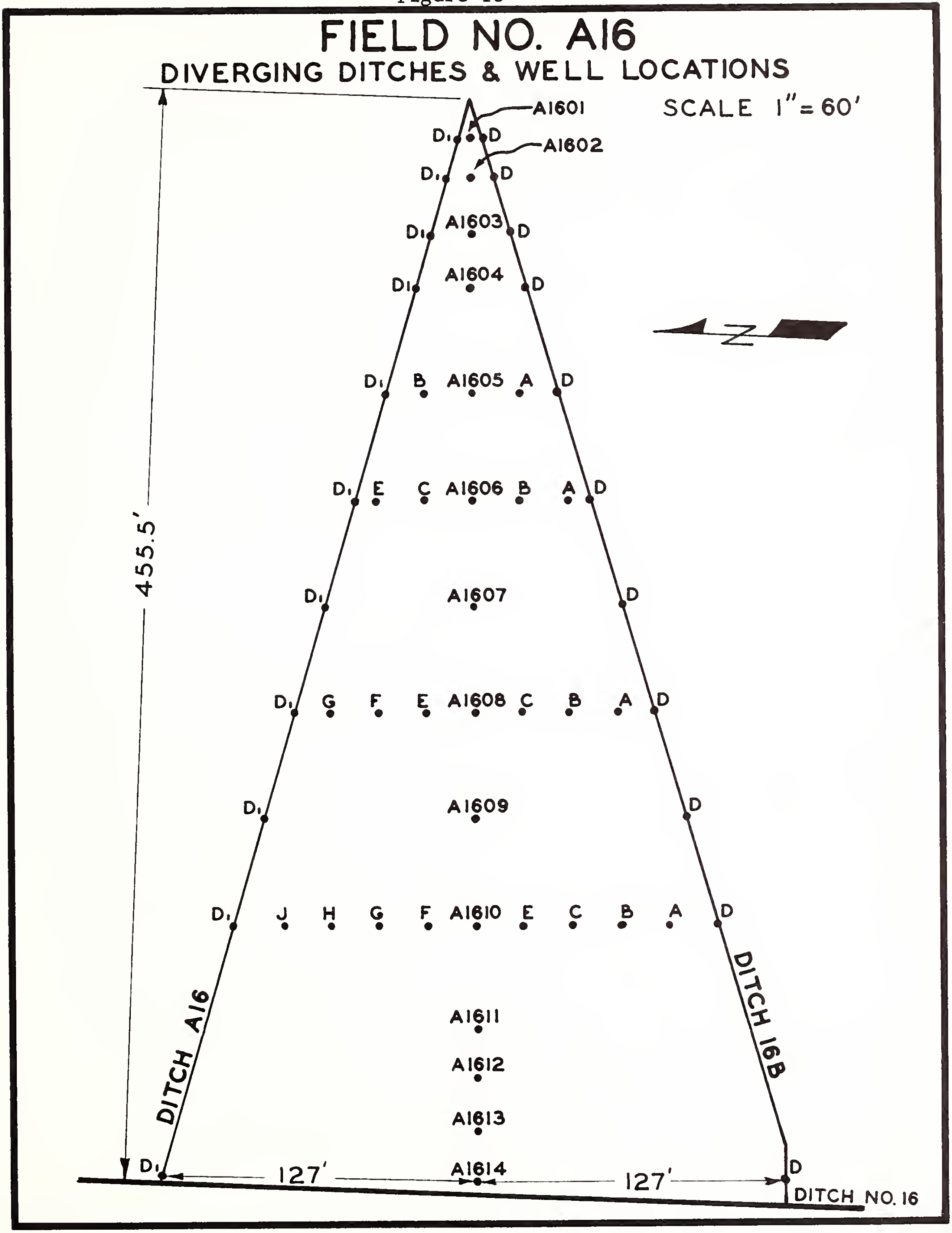
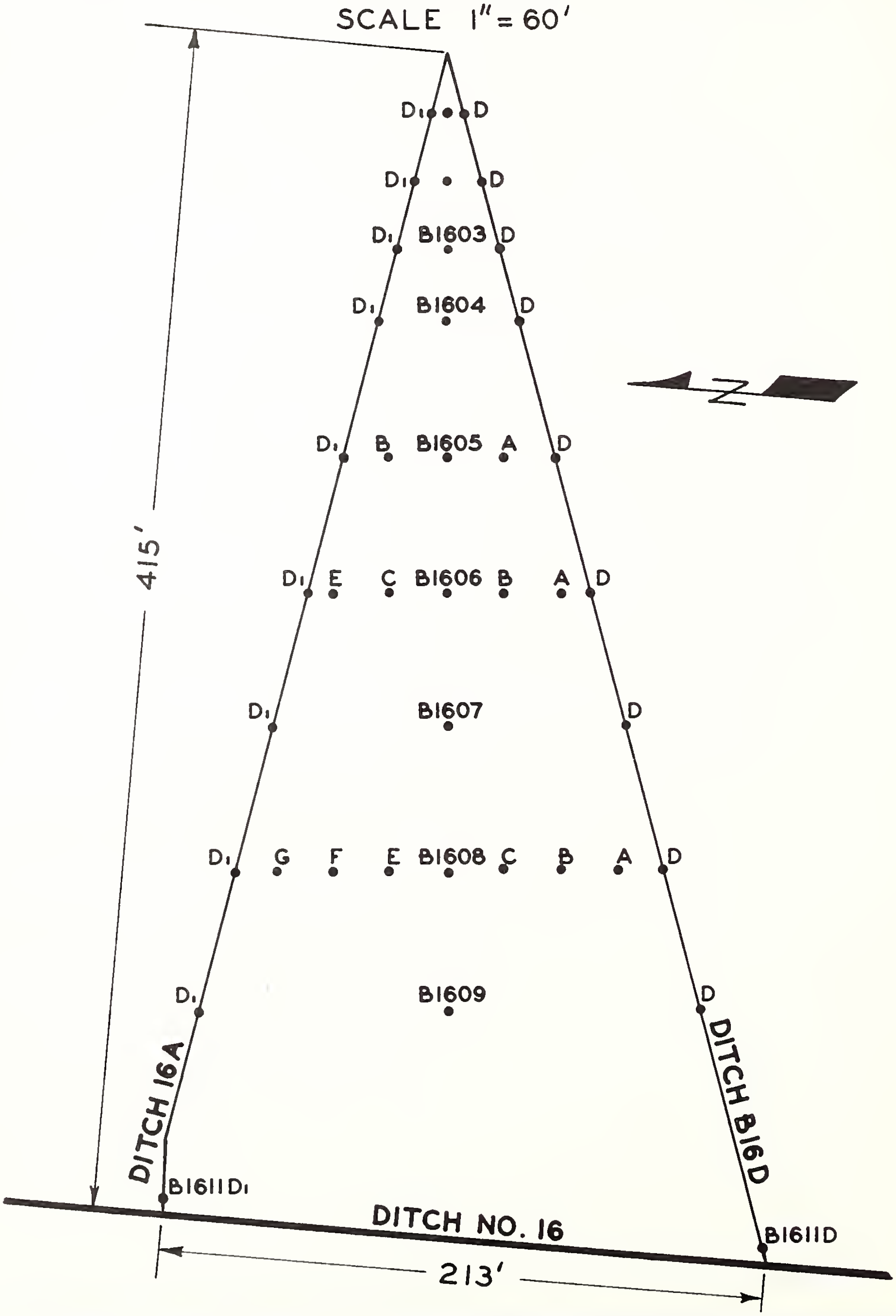

FIELD NO. A16
DIVERGING DITCHES & WELL LOCATIONS
SCALE 1" = 60'
N
455.5'
127'
127'
A1601
A1602
A1603
A1604
A1605
A1606
A1607
A1608
A1609
A1610
A1611
A1612
A1613
A1614
A B C E F G H J
D
D1
DITCH A16
DITCH 16B
DITCH NO. 16

Figure 19

FIELD NO. B16

DIVERGING DITCHES & WELL LOCATIONS

SCALE 1" = 60'



16 are shown in Figure 18 and 19 .

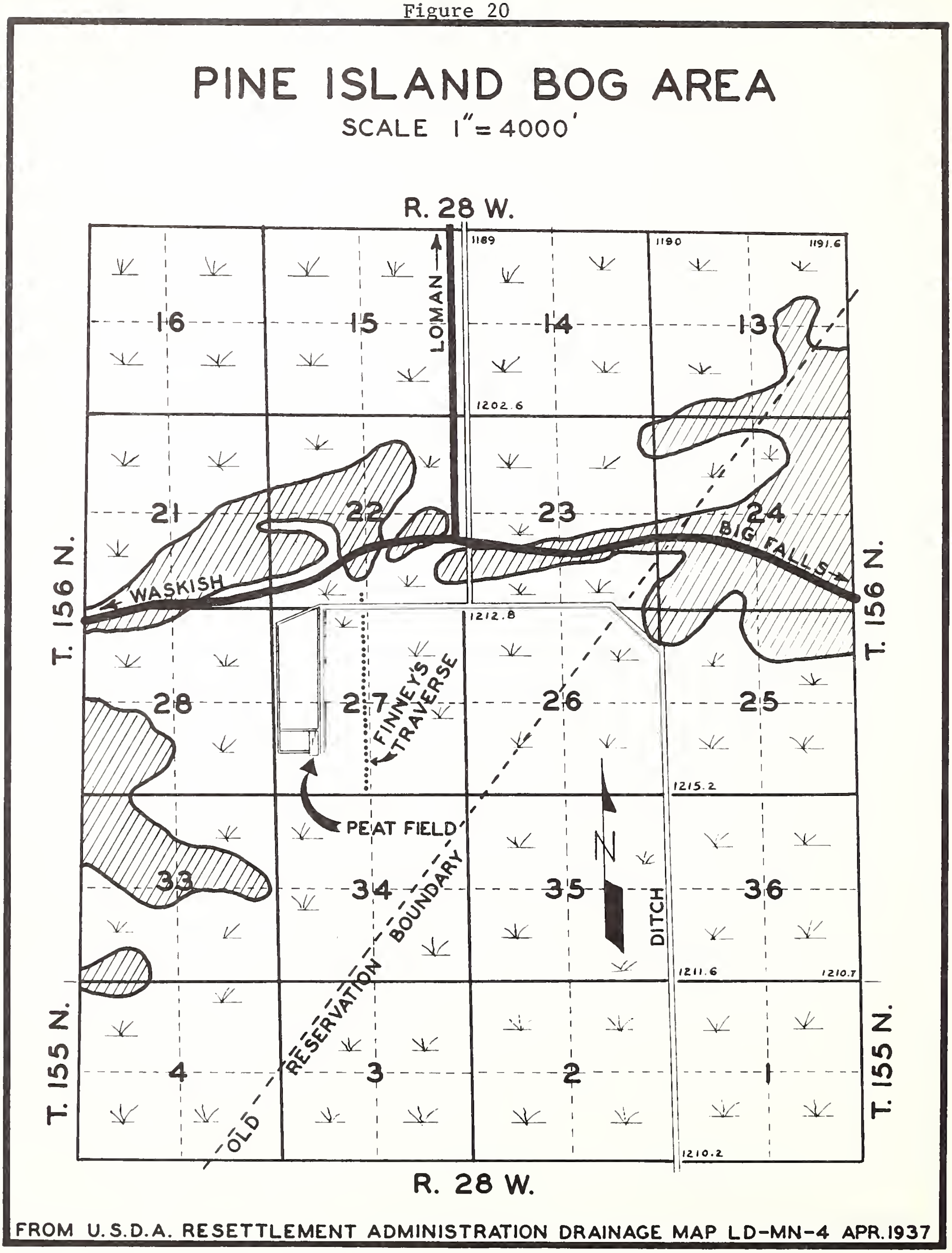
2. Development of the Pine Island Sphagnum Research Area

Through special permission of The Chun King Corporation, land held by them under lease was obtained for studies in sphagnum, paralleling those on Reed Grass Sedge peat at Wilderness Valley Farms. The bog is located 25 miles northwest of Big Falls in Koochiching County (Sec. 27, T. 156, R 28) and was originally surveyed and leased by Chun King in 1960. In the winter of 1960-1961 they dug 3¼ miles of new ditch and deepened a half mile of old ditch. Two of these ditches were put in parallel to each other and the castings placed between to form a bed for a roadway, terminating midway in the SW¼ of the section (See Figure 20). The trees on a 20-acre tract extending the full distance between the south ends of the western-most ditch and the parallel ditches were knocked flat this same winter with a medium-sized crawler tractor (J.D. 10-10) and dozer. The eastern-most end of this area was selected for the development of the research field.

Early in July, 1965, the castings between the parallel ditches were dozed level to provide access via jeep to the selected area. A dragline and operator were secured and the dead spruce and muskeg was dragged from the surface. The 3/4 yard bucket was outfitted with 3 24-inch teeth. The surface material was removed to a depth ranging from 6 inches to 18 inches and was composed of the normal muskeg plants of the area: Labrador tea, leather leaf, bog laurel, blueberry, cranberry and sphagnum, hypnum and haircap mosses. The water table was at the surface of the exposed sphagnum body and all work had to be done from matts. Concurrent with the removal of the muskeg the main ditch across the north end and that along the west side was dug with the dragline. The inner, crank-shaped ditch, 20-inches wide, was put in with the I.R.R. & R. Bombardier backhoe (See Figure 21). This rig put in 350 feet of ditch on this field plus another 75 feet of repairing and completion of the west boundary ditch at the south end. Preliminary wells were put in as the cover was removed to chart the water loss from virgin bog. Because of the extreme wetness of the newly exposed peat and the overabundance of rain late in September, no work could be done in bringing the fields into harvestable condition in 1965. Some trouble was encountered in putting the ditches on peat so fresh and undrained. At several places the ditches almost closed as the supersaturated, "plastic"-peat body sagged to fill the void of the fresh ditch.

The Bombardier crew also installed a diagonal ditch on the opposite side of the roadway, labelled Field 6 on Figure 21,

Figure 20

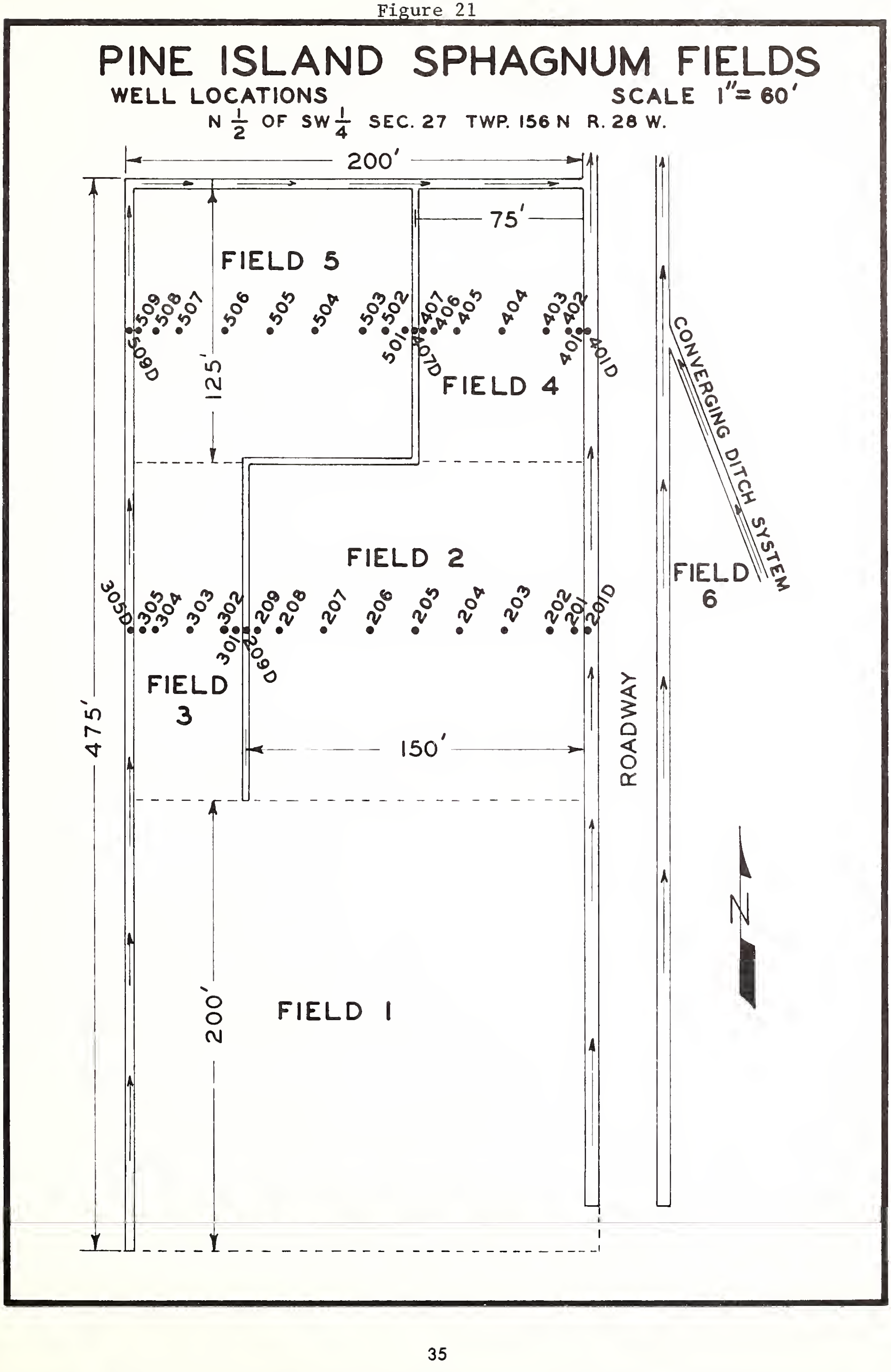


PINE ISLAND BOG AREA

SCALE 1" = 4000'

FROM U.S.D.A. RESETTLEMENT ADMINISTRATION DRAINAGE MAP LD-MN-4 APR. 1937

Figure 21


PINE ISLAND SPHAGNUM FIELDS
WELL LOCATIONS
SCALE 1" = 60'
N 1/2 OF SW 1/4 SEC. 27 TWP. 156 N R. 28 W.
200'
75'
125'
475'
150'
200'
FIELD 5
FIELD 4
FIELD 2
FIELD 3
FIELD 1
FIELD 6
ROADWAY
CONVERGING DITCH SYSTEM
N
509
508
507
506
505
504
503
502
501
509D
407
406
405
404
403
402
401
401D
407D
305D
305
304
303
302
301
209
208
207
206
205
204
203
202
201
201D
209D

to provide comparative figures with Fields 16, A16, B16 at Wilderness Valley Farms.

Some 6,000 cubic yards of muskeg and peat were removed to expose a field of 2.18 acres and install the main ditch on the north and west.

In the 1966 season, a series of wells at 300 foot intervals were installed on a line identified as undrained bog. The general location of this line is shown in Figure 20. The well layout and numbers will be found in the section discussing the data collected along the traverse in the undrained sphagnum bog (See page 68).

Further development of the sphagnum area was delayed until the 1967 season when that facility was staffed and the fields readied for data collection.

The roots were hand picked and carried from the fields. The surface was then leveled with a small dozer and two sections of a spike-tooth harrow. Wells of the same type as used on the Reed Grass Sedge Peat at Wilderness Valley Farms were inserted. They were leveled in and identified as shown in Figure 21. The converging ditch on the east side of the access road was also fitted with wells to approximately the same pattern as used at the Farm. This proved a tedious job as lines had to be hand cut through the black spruce natural cover -- all work being done on the hummocky, spongy terrain of the raw bog. The spacing and identification of the wells is shown in the accompanying Figure 22.

The quality of sphagnum peat in this facility is of the best and the data reported can be reliably related to any bog where the peat can be legally identified by the term sphagnum. The whole of this bog comprises over 1,000 acres of prime peat, the research field being located at about the middle of the raised center of the bog.

C. Results and Conclusions

1. Drainage experiments with Reed-Sedge Peat - Wilderness Valley Farms

One of the basic decisions to be made in setting up a peat operation involving field drying of the product is the character of the drainage system.

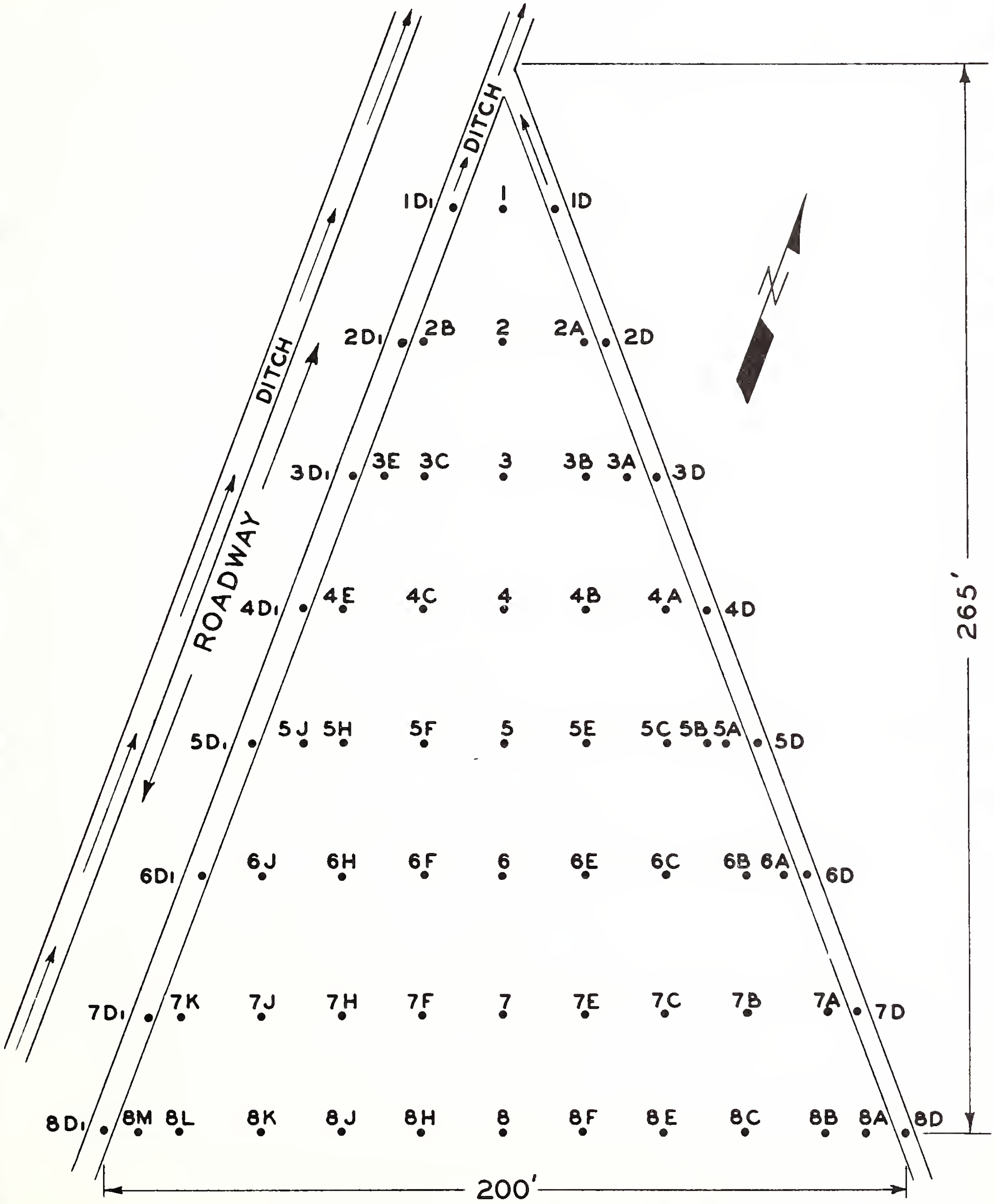
Three years of data gathered at the Wilderness Valley Farms, Peat Research Facility provide figures and observations from which the statements following are drawn.

Figure 22

PINE ISLAND

CONVERGING DITCHES & WELL LOCATIONS

SCALE 1"=40'



Distance Between Ditches (Field Widths) -- The converging ditch system, Field No. 16, was designed to provide definite data on drainage. The system includes two 18-inch wide, straight-walled trenches dug to the bottom of the peat bed, beginning at points 400 feet east of the outlet and converging from their beginnings (215 feet apart) to a common mouth. Along a straight center line bisecting the triangular field, perforated, aluminum "wells " were driven at 44-foot intervals. During late fall of 1966 and early spring of 1967 this system was expanded to include two diverging systems one on either side of field 16. This was done to determine what if any effect the open end of field 16 would have in allowing water to funnel in from the raw bog. (A review of the well data for these fields show conclusively that harvest fields must be separated from the raw bog by a ditch. See page 43 . Commencing with August, 1966, the water levels were read periodically until the close of the season and repeated in 1967. Rain of various rates and frequencies makes much of the data of only passing interest, but from five separate periods of 5-day duration in the 1966 season the following chart is presented which is felt to be of significant value.

Well No.	Corresponding to a Field Width of	Drop in Water-Level In Inches				
		May 23-27	June 14-18	Aug. 8-12	Aug. 15-19	Aug. 23-27
1604	50'	4½	5	7	8½	7
1605	75'	4½	3½	7	8	6
1606	100'	4	2½	6	6½	4½
1608	150'	3½	3½	5	5	4
1609	175'	2½	2½	4	5½	4½
1610	200'	2½	2½	3½	5	3½
Rainfall at start of period		.22	.785	3.87	.815	.90

In addition to the information from the converging ditch system, which was under a native herbacious cover (grasses and herbs), data from five cultivated fields is presented in the following chart under the same headings and for the same period.

8C5	50'	2½	2	10½	7½	8½
8W5	50'	4½	2½	11 *	9	7½
8E5	50'	4½	2½	11½	10	8½
7E8	75'	5½	2½	8 *	8	5½
911	150'	3½	1½	3½*	10	8½

The trend is not so easily followed from this chart because of some apparently important effects that the varying methods of field surface preparation had upon the rate of water penetration and loss.

However, attention is called to the three starred readings which the authors feel are indicative of the basic trend when the effect of the variant factors are minimized by a very heavy rain.

The shape of the water table at the various well positions is diagramed for field No. 16 in Figure 23. We do not know how much of the rain ran off the surface rather than percolating down, but it seems safe to assume that the narrow fields would lose more than the wide. However, the relative gentleness of the precipitation plus the grassy cover would tend to reduce this to a minimum. The soil level is for the 1610's only -- the field surface gently slopes southwesterly -- for instance, the comparative soil surface at point 1601 is about five inches lower than that diagrammed. The relative positions of the water table itself are, however, faithfully portrayed.

The authors have observed that until the water level in the wells is at least twelve inches below the surface of the soil that the fields are too soft to support heavy harvest equipment. Further, since adequate drying is directly related to the fluffing of the field surface, the rate of the water table recession is of real interest. Drawing again from the converging ditch data, the rate of water table recession is looked at from the practical consideration of how quickly an operation could enter the field after a heavy rain.

RATE OF WATER TABLE RECESSION (1966 DATA)

Well No.	Field Width	Inches below Soil Surface to Water	Days to Fall to		
			12"	18"	24"
1601	12½	21	-	-	1
1602	25	15	-	1	3
1603	37½	9½	1	3	11
1604	50	7	3	11	29
1605	75	4	9	22	35
1606	100	5½	10	24	35
1607	125	3	11	29	42
1608	150	½	29	39	66
1609	175	1	29	42	This level not reached.
1610	200	3½	26	39	

It should be noted that for fields in which the drainage pattern might follow that of our system for all widths of 75 feet and over much precious time is lost every time a heavy rain occurs. Of course, the long periods of over a week's duration are all elongated by each rain that falls, big or little. While the very narrow fields had drained to a level

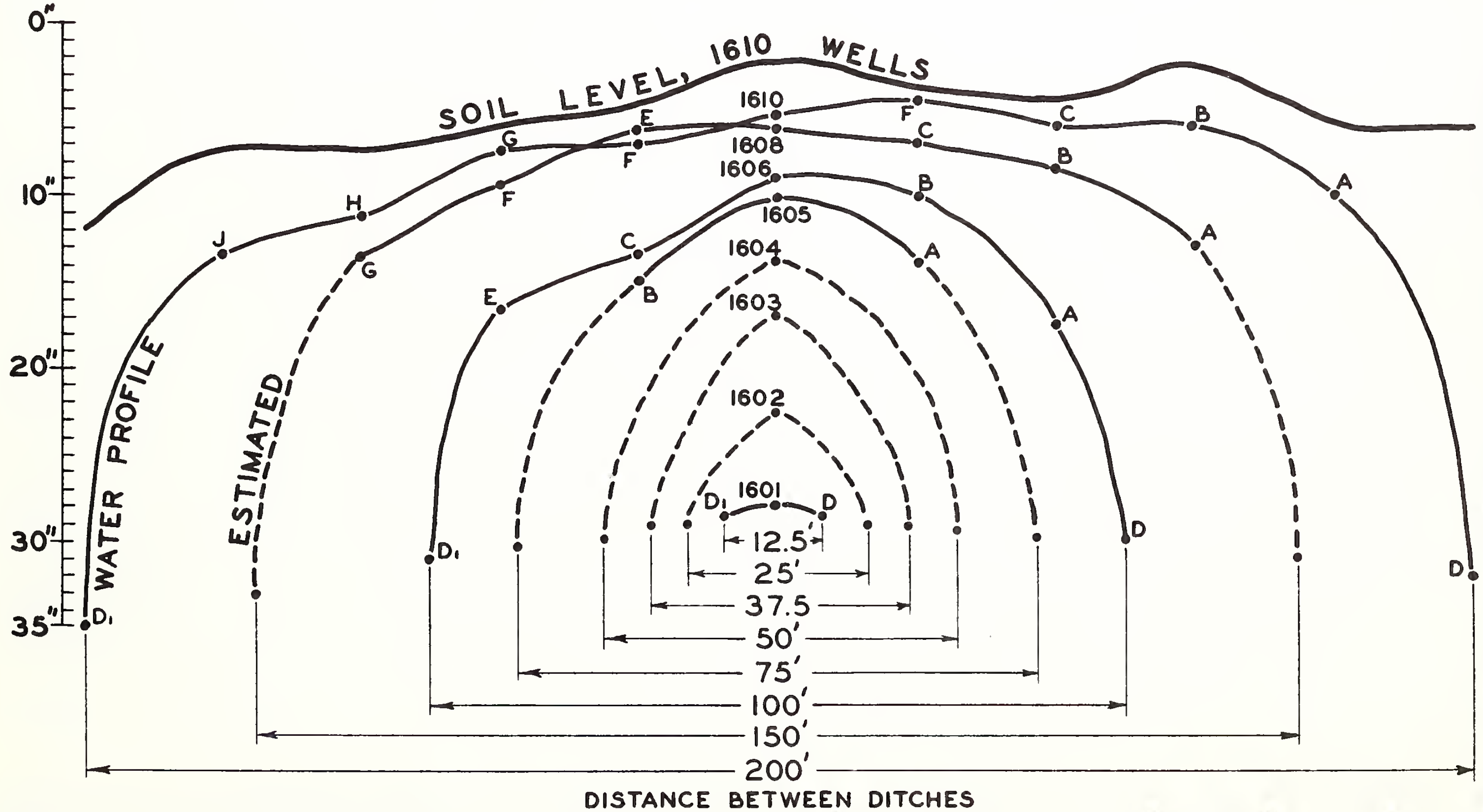
Figure 23

THE SHAPE OF A 3" RAIN THE DAY AFTER

FIELD 16

CONVERGING DITCHES

3.75" RAINFALL ON 8-6&7-66



below that rechargeable by this amount of rain, harvest management would certainly be complicated by their narrowness and the development cost of the bog could be high because of the great increase in the ditch footage per acre. It would, however, appear that serious thought should be given before fields were laid out over 100 feet in width.

The shape and size of the capacity to absorb rain after an extensive dry period is diagrammed for field No. 16 in Figure 24. The soil surface is at a point 22½ inches above the graph line at points 10 and 8, 29 inches above points 6 and 5, 30½ inches above 4, 33½ inches above 3, 36½ inches above 2, and 40 inches above 1.

Now, returning to the discussion of the rate of water recession -- when similar data is examined from the cultivated fields the same pattern of response is noted, though not so extreme as the rates on the "green field."

RATE OF WATER TABLE RECESSION (1966 DATA)

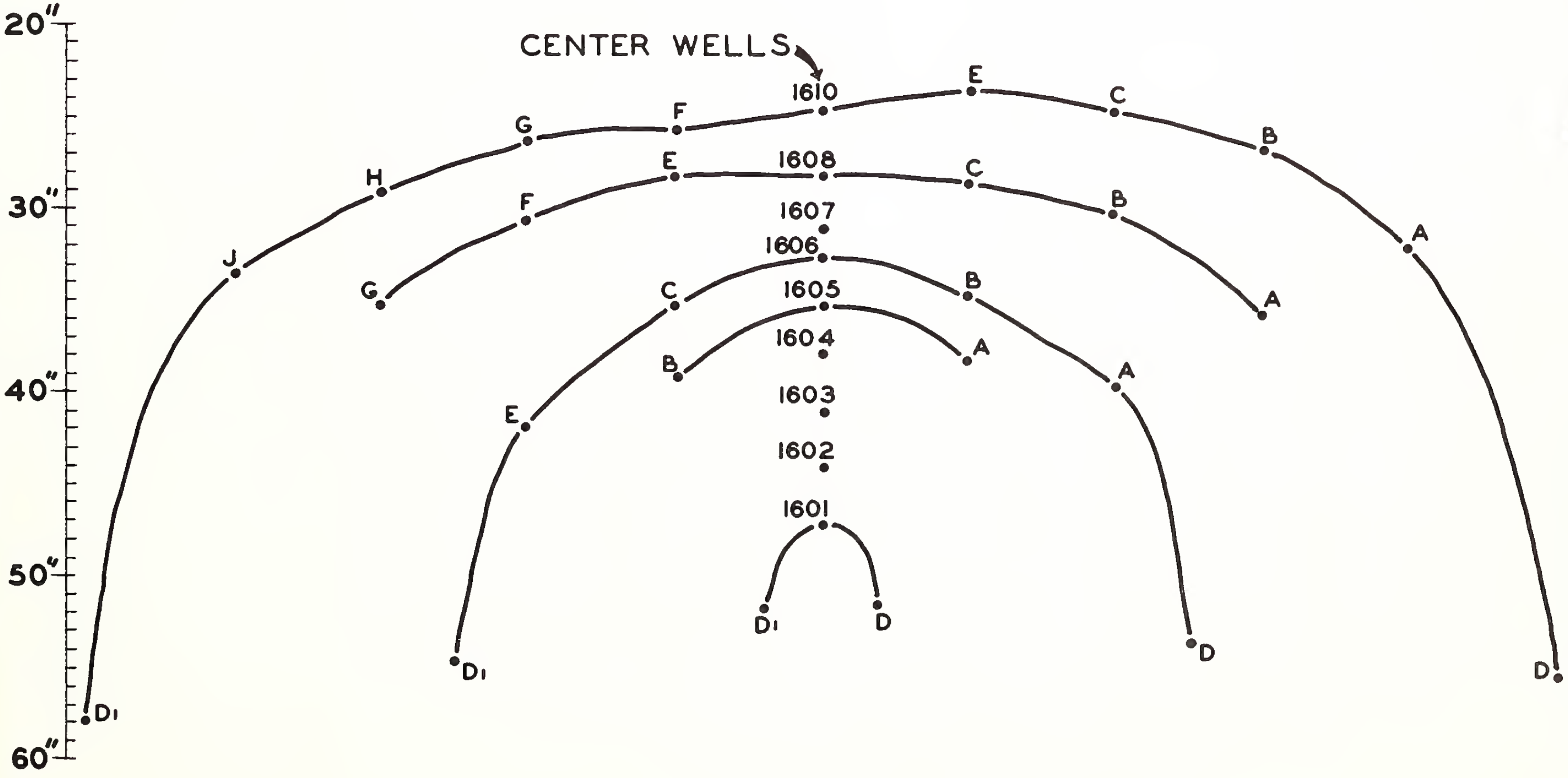
Well No.	Field Width	Inches below Soil Surface to Water	Days to Fall to 12"	18"	24"
8C5	50'	12½	-	2	8
8W5	50'	8½	1	4	10
8E5	50'	8	2	4	10
7E8	75'	10½	1	4	11
918	150'	3½	4	10	20
904	150'	7	4	14	32
911	150'	5	10	21	25

That two sites involving 150' width yielded acceptable figures for the twelve inch minimum should not eliminate the possibility that other fields might follow the trend of 911. All of the wide fields required an unsafely high number of days to pull down to a "safe" 18" margin (or probably an even wiser aim of 24"). It has been observed that with such safety margins the fields can handle a great number of lesser rains without retiring the harvest machinery for long, costly waiting periods.

An attempt to remove the effects of intervening rains from the chart is presented in the following discussion. This was done by counting only the days of a dropping table, deleting the days of rain and rising table and only resuming count when the fall had reached the level prior to the day the rain commenced. While it is admitted that the possibility of error is not small, the manipulated figures for both fields present an interesting picture.

Figure 24

PROFILES OF WATER LEVELS. FIELD 16
SEPT. 28, 1966
1" OF RAIN IN PRECEDING 37 DAYS



RATE OF WATER TABLE RECESSION COUNTING ONLY DAYS OF CONSECUTIVE DROP (1966 DATA)

Well No.	Field Width (in feet)	After 3.86" Rain of August 6,7,8, 1966			
		Inches Below Soil Surface to Water Table	Days to Fall to		
			12"	18"	24"
1601	12½	21	-	-	1
1602	25	15	-	1	3
1603	37½	9½	1	3	7
1604	50	7	3	6	11
1605	75	4	5	11	22
1606	100	5½	5	9	21
1607	125	3	9	17	24
1608	150	½	12	20	33
1609	175	1	15	24	Not Reached
1610	200	3½	12	22	
8C5	50	12½	-	3	5
8W5	50	8½	1	4	6
8E5	50	8	2	4	7
7E8	75	10½	1	4	8
918	150	3½	4	6	10
904	150	7	4	9	17
911	150	5	6	9	14

Roughly, it takes as much time for the water to leave the 3rd six inches of the soil as it does for it to pass through the first twelve inches, and it takes nearly as much time for the 4th six-inch layer to drain as it does for the whole of the first 18 inches. When these facts are appreciated in the highest of the inverse relationship between the rate of draw-down and the field width (the wider the field, the slower the water movement) the determination of field width assumes its proper proportion of importance.

CONCLUSION: Fields of raw, reed-sedge peat, with clean ditches having adequate outlet, should have widths which do not exceed 100 feet. For especially designed equipment and certainly for small operators, or where ditching cost might not be exorbitantly high, fields of lesser width will increase the margin of safety drastically and provide some extra days of harvest.

Perimeter Ditching (Isolation) -- It cannot be stressed too thoroughly that the harvest field must be separated from adjacent raw bog areas by a drainage ditch interrupting the water flow from the undeveloped area into the harvest field. This has been the experience of several operators whose fields have been observed by the authors, and until such ditches were installed, harvest was possible only during the most favorable periods. Also, large areas used for piling wastes, stumps, scalpings, etc. must be separated from the fields proper by effective drainage.

From our experimental fields, we had at first surmised that the differences in rate of drop as noted between the broad areas of field No. 16 and the comparable areas of fields No. 7 and 9 were largely due to the growing cover of the former and the fallow condition of the latter. However, when the well tables of field No. 17 which is also under grass are compared with the one well of field No. 16, which is comparable (1604), those of field No. 17 consistently show rates of water loss more like those of the open fields (8W, 8C and 8E). (See Fig.25 on page 45 for example).

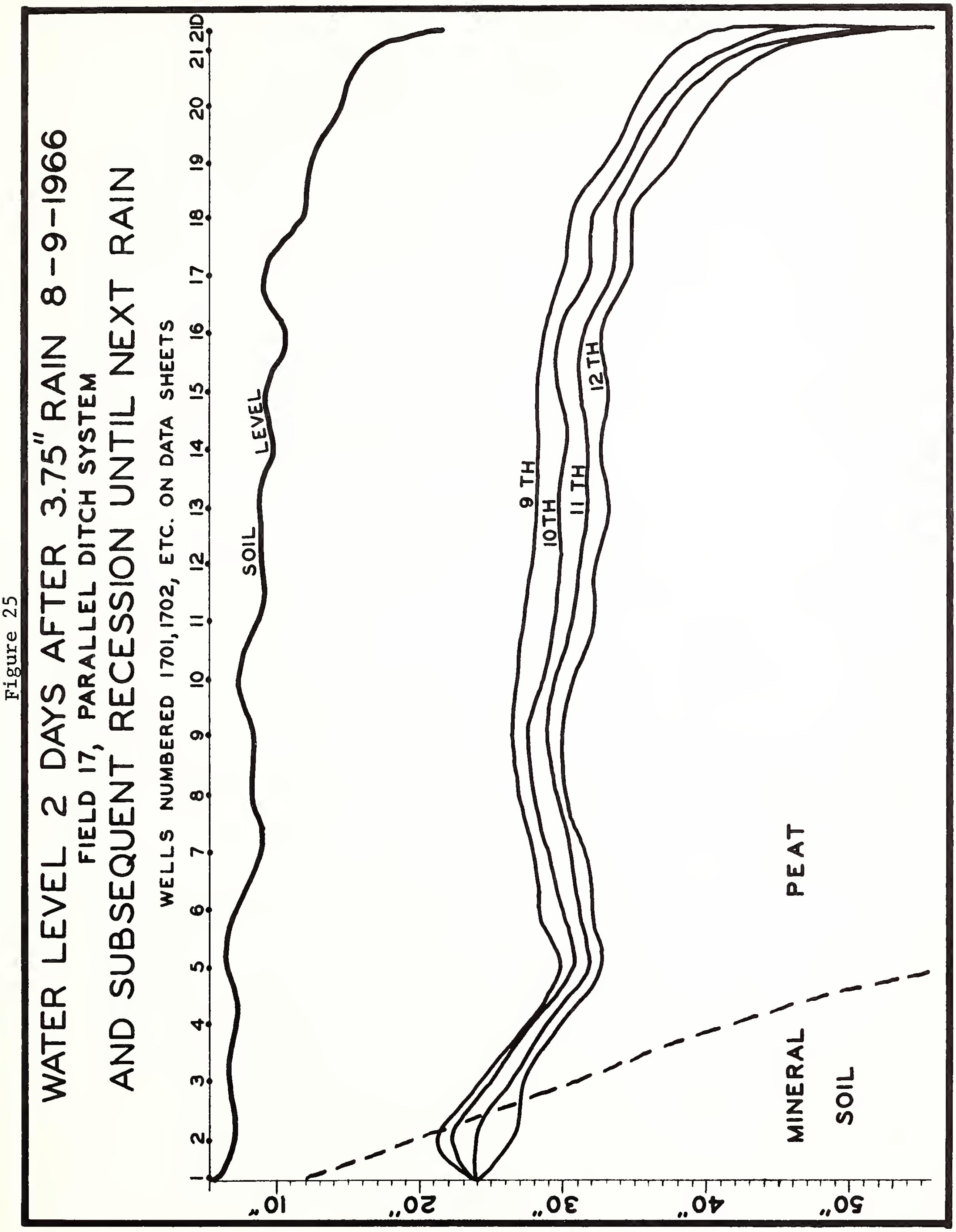
The converging ditch system originates in an open bog not separated by an interrupting ditch. The ditch system is simply a "V", the top ends being dead ends, the point outletting commonly into another ditch. The wide end of the wedge-shaped field is not protected from the raw bog beyond the ditch ends. To aggravate the condition, the field lies in the direction of natural flow from the bog beyond.

WATER LEVEL DISTANCE BELOW SOIL SURFACE
IN 5 FIELDS ALL APPROXIMATELY 50 FEET WIDE

1966 August	1604[1]	1710[2]	8E5[3]	8C5[3]	8W5[3]
9	8.5	20.	10.5	15.0	11.5
10	10.	22.	14.5	18.5	15.
11	11.5	22.5	17.	20.5	16.5
12	14.	24.	19.5	23.	19.5
15	10.5	21.5	17.	20.5	17.
16	12.	23.5	19.5	23.5	19.
17	13.5	25	23	26.	22
18	17.	26.	25.	27.5	24.
19	19.	28.	27.	28.5	26.
22	10.5	19.5	19.	24.5	19.
23	10.5	20.5	18.	21.5	18.
24	11.	21.5	19.	22.5	19.
25	12.5	23.	21.5	24.5	21.
26	15.	25.	24.	26.5	23.
27	17.5	26.5	26.5	28.	25.5
29	20.5	28.5	29.5	30.	28.
30	21.5	29.	30.	21.5	29.5

1. Converging ditch system (under grass)
2. Parallel ditch system (under grass)
3. Developed harvest fields (fallow)

Figure 25



WATER LEVEL 2 DAYS AFTER 3.75" RAIN 8-9-1966
FIELD 17, PARALLEL DITCH SYSTEM
AND SUBSEQUENT RECESSION UNTIL NEXT RAIN
WELLS NUMBERED 1701, 1702, ETC. ON DATA SHEETS

The parallel ditches of field No. 17 run north and south across the normal flow, outletting at the south. The open north end of the field is "plugged" by a mineral island (Figure 25).

Field No. 8 is one of the complex of harvest fields running north and south and "protected" across the north end by a large county drainageway. The only field into which water may enter laterally from an area outside the field is 16.

CONCLUSION: From observations of harvest fields of others and the data as presented in the foregoing discussion it can be dogmatically stated that harvest fields must conform to the normal drainage pattern and be adequately ditched on all sides to prevent the lateral seepage of water from the undeveloped surrounding bog or from runoff of higher mineral soil.

Pumping for Drainage -- In areas where bog acreages are large, field slope is gentle and where outlets are often inadequate to facilitate rapid drainage, pumping may be in order. By excavating a good canal across the low end of the fields and using the excavate as a dike on the outside of the area and constructing a dam at the normal outlet with a low-level lift pump of adequate capacity could rapidly empty the canal as filled by the feeder field ditches. The dam, of course, would prevent the outlet from backing up into the fields. This system was tried the fall of 1966 and repeated in 1967 on a part of field No. 7E.

A Demming irrigation pump with a 6-inch intake and powered by a Chrysler industrial gas engine was used to pump the water from or back into the ditches. In 1966 trouble was experienced in operating the equipment until adequate screening of the intake was finally obtained. Because of this, it was not possible to maintain a constantly uniform head in the ditches. However, only infrequently did the ditch level reach an equilibrium even with the nearest wells (the "A"'s) and then only for a relatively short period of time. The water was pumped from the experimental field ditches into the large "county ditch." This same ditch also served as the source for pumping water back into the field ditches. During the pump-downs, the pump was set at the northeast corner of the field and then moved across the road to the side of the county ditch for pumping back.

Wells were read from September 2, 1966 through October 31, 1966. Over 2700 well readings were taken during this period at intervals of from 30 minutes, 1 hour, 2 hours and longer periods to carefully document the initial movement of the water and to adequately chronicle the movement over a lengthy period of control. (In 1967 similar readings began on August 8 and continued through October 10).

Only the 1966 data is referred to in the following discussion.

The first pump down period ran from September 2 through September 27. Exactly .612 inches of rain fell during this period and the water-level of the outer well (7E3) dropped 13 inches, an average of one-half inch per day. While there were two showers of about one-quarter inch each (9/3-.23 and 9/13-.29) neither made any noticeable difference in the rate of fall. The actual rate, breaking the period into stages, showed that during the first ten days the center of the water table dropped .7 inches per day; that during the next seven days the average declined to .43 and that the rate dropped during the next eight days to .38 inches per day.

On September 28, the pump was reversed and the ditches were filled to the top; re-entry of water proceeded at a rate about 50% greater than the rate of initial decline. Midway in the period a little more than an inch of rain fell in two days and made a marked effect upon the rate of rise: 1½ inches for each of the next two days.

By this time the water level of the central well was back at its old level and the action was again reversed and pump-down proceeded for the next ten days. The center well again began to drop at one-half inch per day. After three days of pumping, an .81 rain fell and reversed the action to a rise of 4 inches in 5 days. During the next 7 days it again fell at the rate of 1 inch per day and during the following week the rate fell to .66 inches per day.

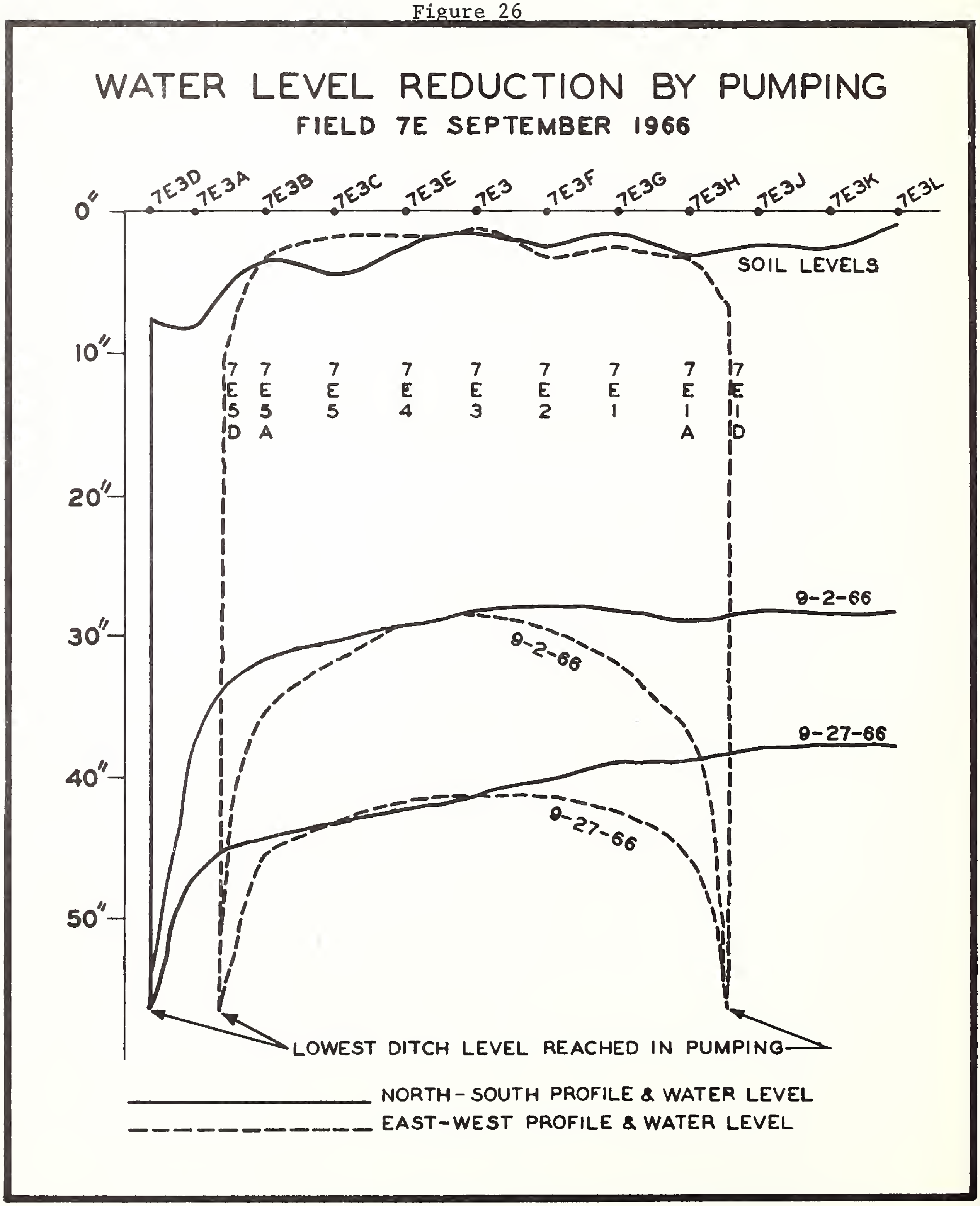
Figure 26 gives the data on water-level reduction by pumping in September, 1966. Figure 27 shows data for pump-down for October, 1966.

Figure 28 shows data where water-levels are rising due to pumping into the ditches.

CONCLUSION: Such data as shown here are extremely important to a peat producer so that he can know what to expect if he has to quickly lower the water levels after heavy rains by pumping.

There is no doubt in the authors' minds that a supplementary pumping system for a large peat harvest undertaking would be necessary to minimize the effects of heavy rains. The installation cost would be small compared to the value of the

Figure 26



WATER LEVEL REDUCTION BY PUMPING

FIELD 7E SEPTEMBER 1966

Figure 27

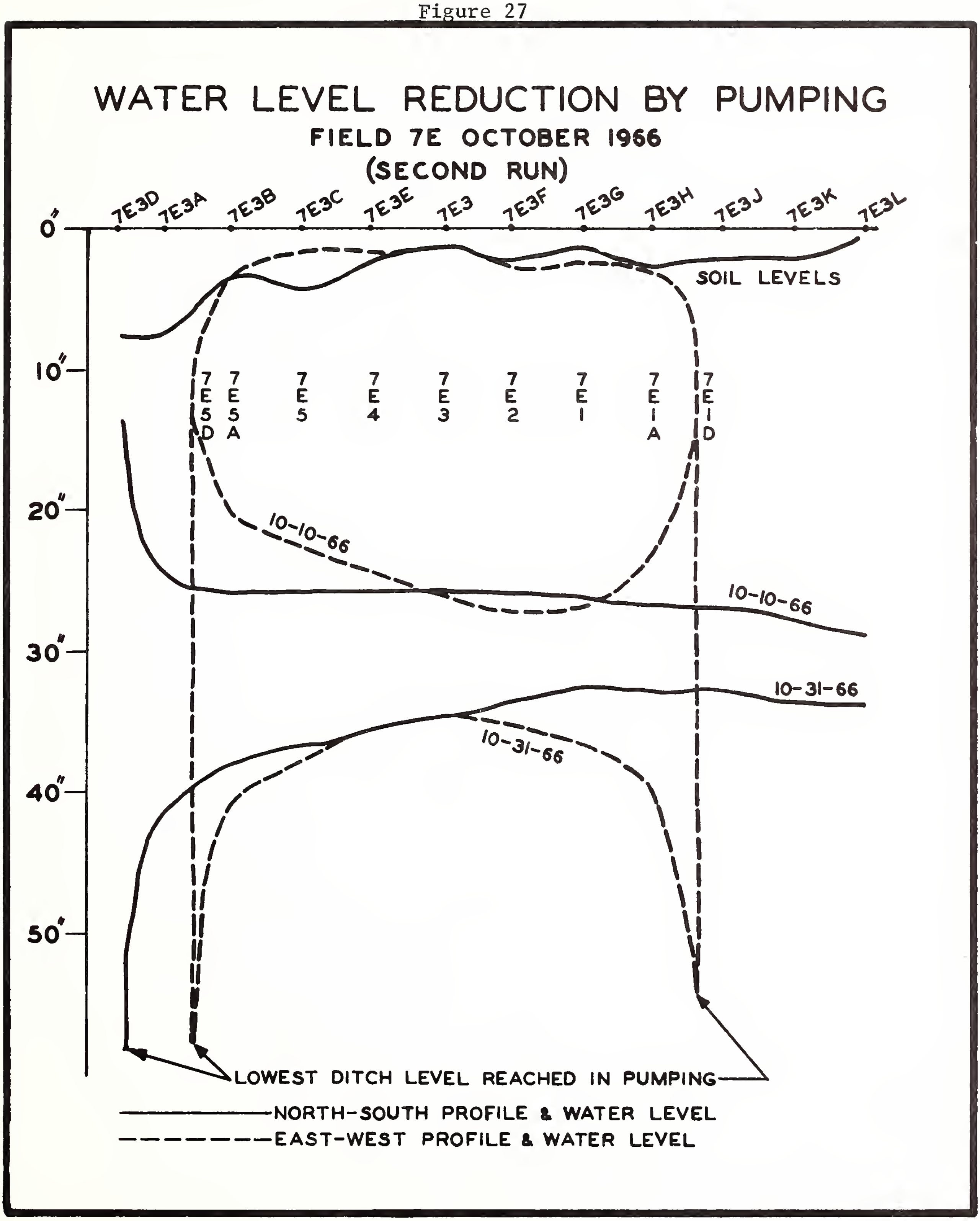
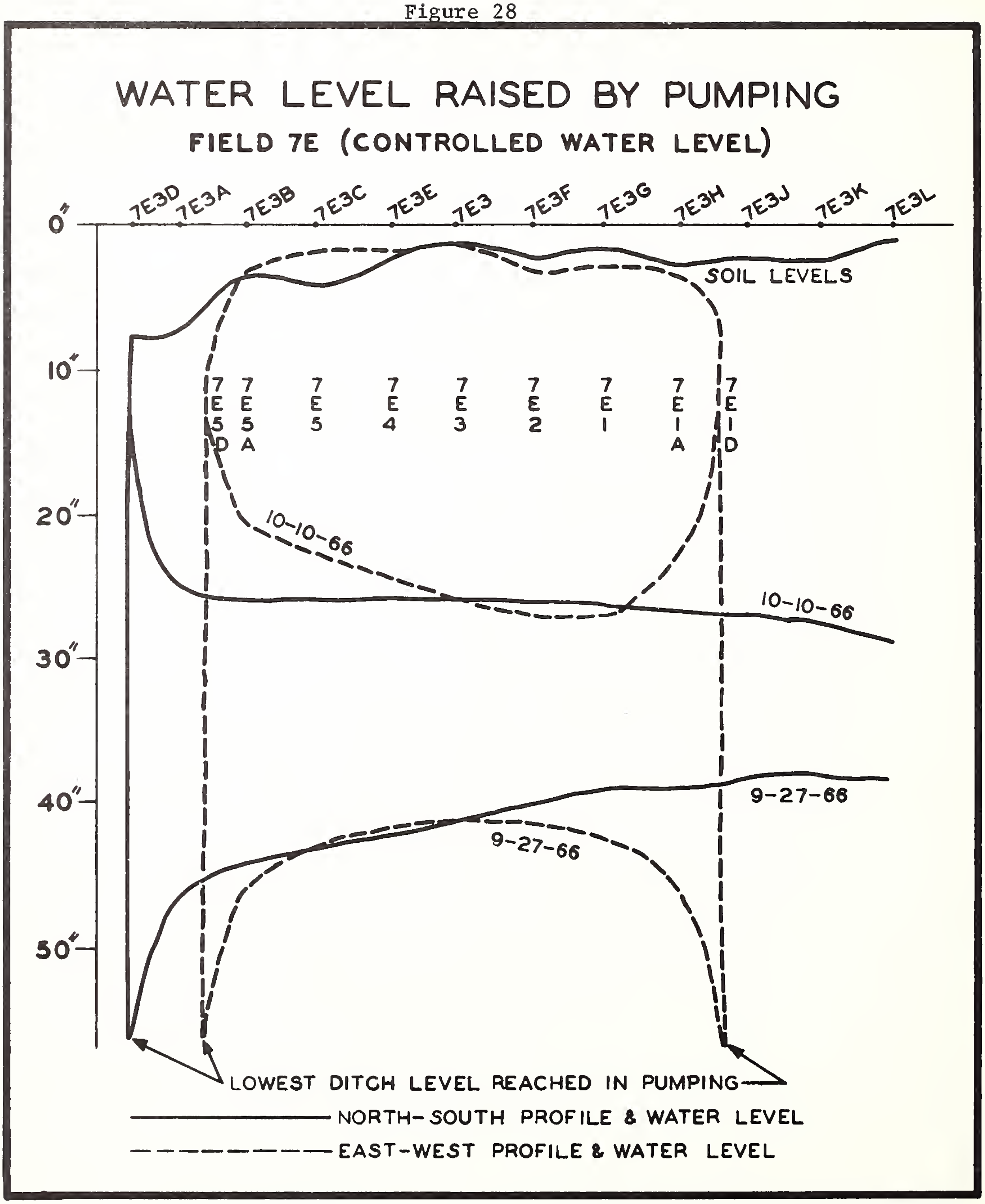

WATER LEVEL REDUCTION BY PUMPING
FIELD 7E OCTOBER 1966
(SECOND RUN)
7E3D
7E3A
7E3B
7E3C
7E3E
7E3
7E3F
7E3G
7E3H
7E3J
7E3K
7E3L
0"
10"
20"
30"
40"
50"
SOIL LEVELS
7E5D
7E5A
7E5
7E4
7E3
7E2
7E1
7E1A
7E1D
10-10-66
10-10-66
10-31-66
10-31-66
LOWEST DITCH LEVEL REACHED IN PUMPING
NORTH-SOUTH PROFILE & WATER LEVEL
EAST-WEST PROFILE & WATER LEVEL

Figure 28


WATER LEVEL RAISED BY PUMPING
FIELD 7E (CONTROLLED WATER LEVEL)
7E3D
7E3A
7E3B
7E3C
7E3E
7E3
7E3F
7E3G
7E3H
7E3J
7E3K
7E3L
0"
10"
20"
30"
40"
50"
SOIL LEVELS
7E5D
7E5A
7E5
7E4
7E3
7E2
7E1
7E1A
7E1D
10-10-66
10-10-66
9-27-66
9-27-66
LOWEST DITCH LEVEL REACHED IN PUMPING
NORTH-SOUTH PROFILE & WATER LEVEL
EAST-WEST PROFILE & WATER LEVEL

time gained in waiting for natural drainage to take away the excess water.

The Parallel Ditch System -- Field No. 17 was laid out with the hope of obtaining data that would show the effect of a sloping floor upon the drainage of a peat bed. Preliminary and minimal soundings seemed to indicate that the area above described would provide an adequate field from which to collect the information. Two parallel ditches about 50 feet apart (on centers) were dug from a mineral island cropping out at bog level, and south 500 feet to the outlet ditch. Wells were inserted at 25-foot intervals down the center of this field. Shortly thereafter a carefully measured floor profile, sampled at 25-foot intervals, together with observations at the ditches, presented a true picture of the floor. Figure 29 shows the field layout and a top and bottom profile of the peat body. The bed slopes sharply from the mineral island reaching its lowest point in 140 feet and then gently rising over the next 250 feet to a bar 15 inches above the lowest point of the bed, thence sloping in the next 75 feet to a new low (by three inches) and then gently rising a few inches in the last 25 feet before reaching the boundry ditch.

Figures 30 and 31 show water table slope and recession in this field. The first figure shows the orderly drop in water table to proceed in an almost equal manner throughout the whole length of the field. The slope conforms much more closely to the surface than to the floor of the bog. The data diagrammed covers the last week of August, 1966. The second figure again indicates that after another month of drainage, the general slope of the water level coincides with the surface contour; in fact, the "bar" at well 1717 does not seem to impede the water movement. The reason for the water table swinging up near the island is probably due to the slow infiltration of water through the mineral layers below.

2. Drainage experiments with sphagnum moss peat - Pine Island 1967

At our Pine Island Sphagnum peat experimental field in Koochiching County, Minnesota, the rainfall was much below normal for August and September. The total rainfall for August was 1.46 inches and for the 1st half of September only 0.53 inches. This was only 1.998 inches for the month and one-half period.

Table 1 shows the rainfall data by days from May 1 through September 15, 1967.

Figure 29

PARALLEL DITCHES FIELD NO. 17

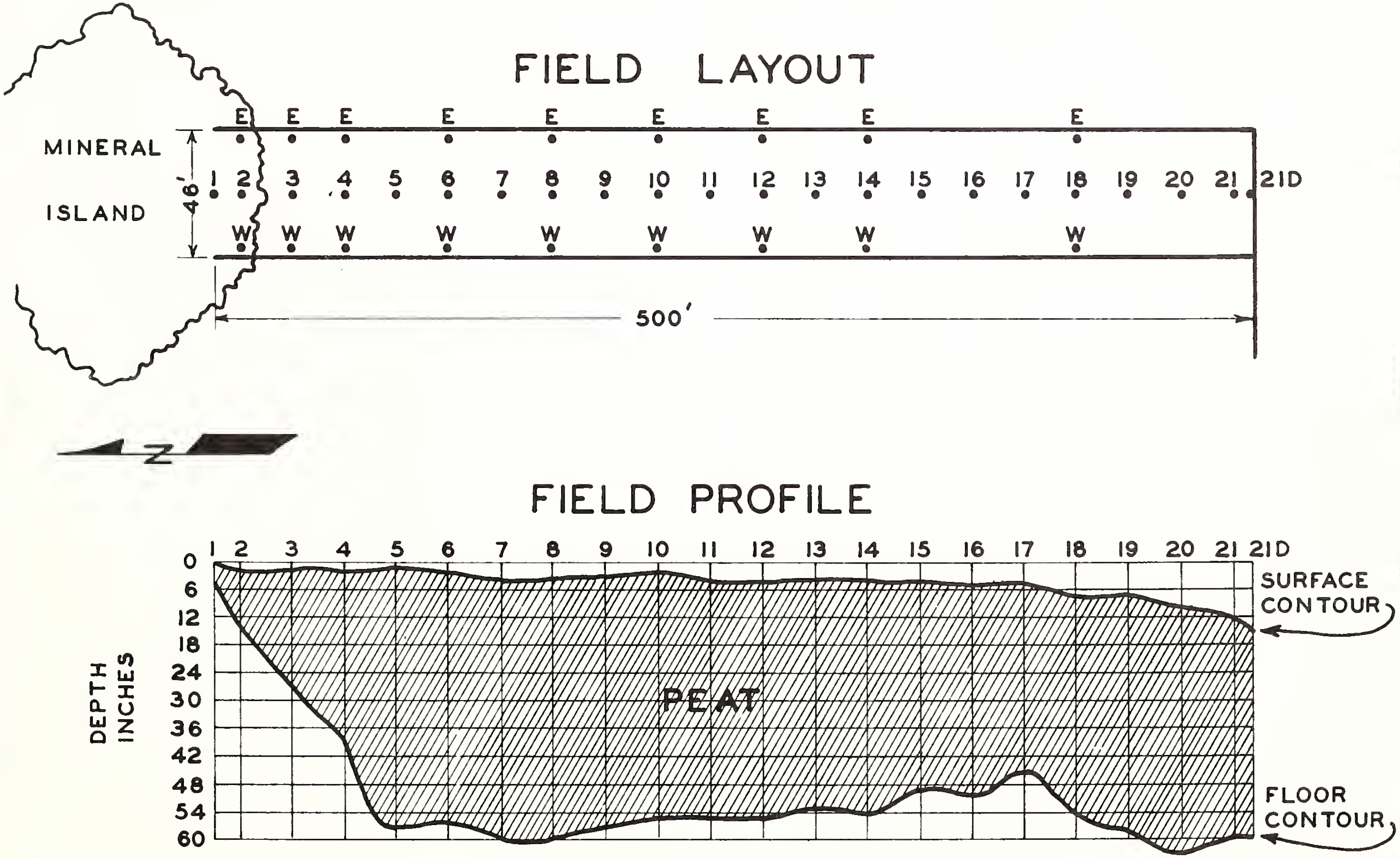
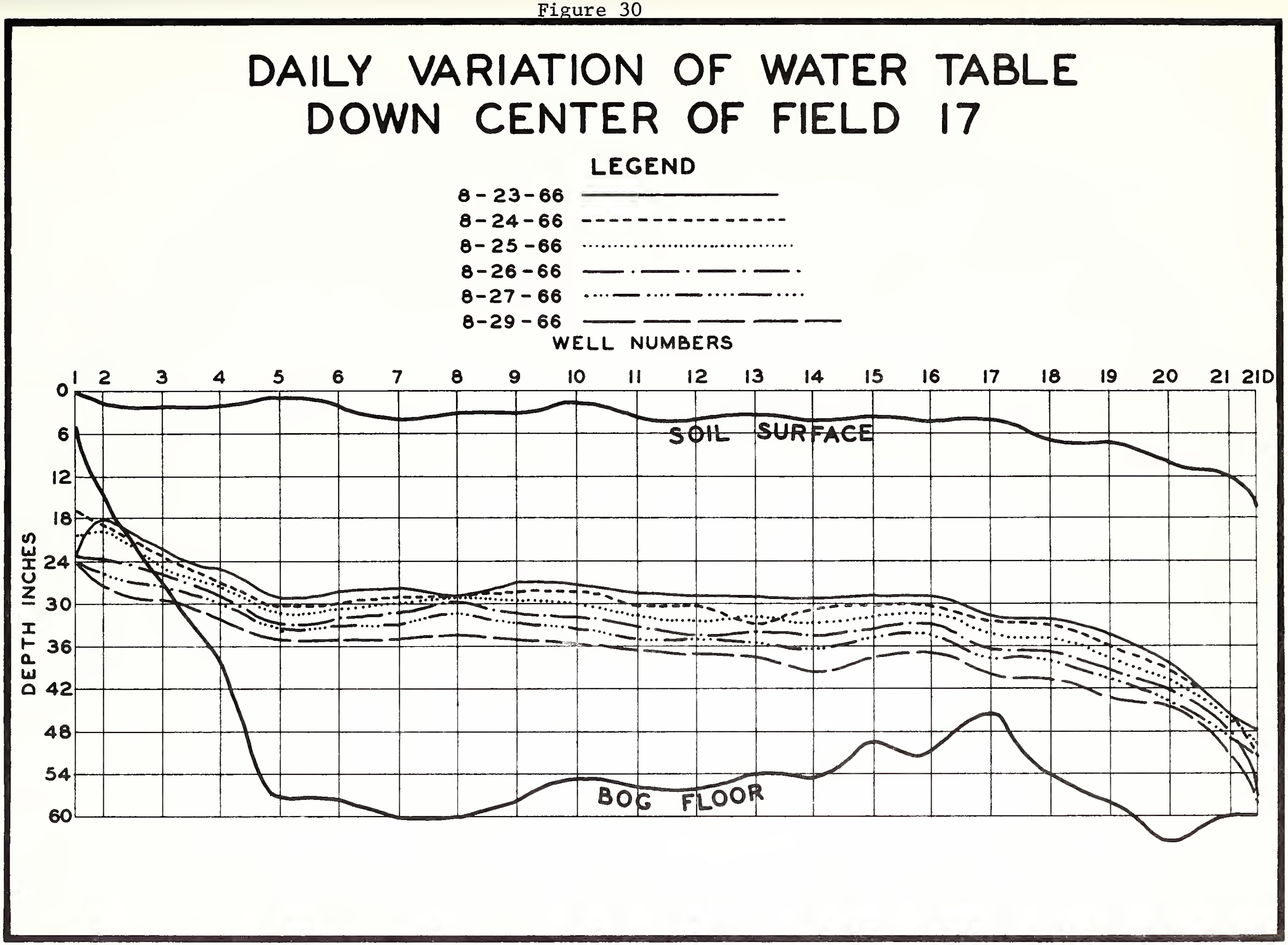


Figure 30



DAILY VARIATION OF WATER TABLE DOWN CENTER OF FIELD 17

Figure 31

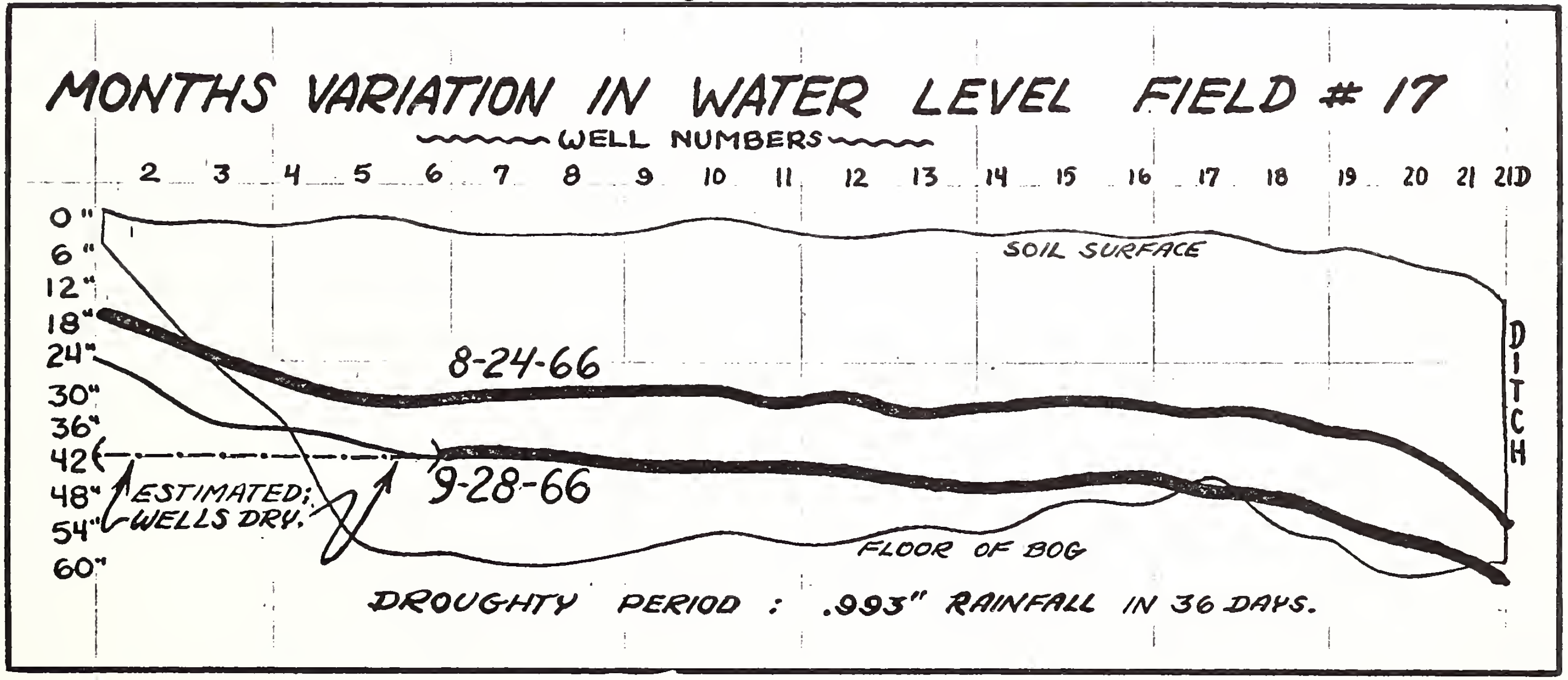

MONTHS VARIATION IN WATER LEVEL FIELD # 17
WELL NUMBERS
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
21D
0"
6"
12"
18"
24"
30"
36"
42"
48"
54"
60"
SOIL SURFACE
8-24-66
9-28-66
ESTIMATED;
WELLS DRY.
FLOOR OF BOG
DITCH
DROUGHTY PERIOD : .993" RAINFALL IN 36 DAYS.

TABLE 1. PINE ISLAND RAINFALL - 1967

May

1	.47
2	.10
4	.01
7	.06
10	.27
11	.02
20	.07
23	.11
26	.49
27	.14
29	.30

June

6	.27
8	1.47
12	.35
13	.06
14	.30
19	.76
20	.26
21	.06
26	.49
27	.28
28	.75
29	.30
30	.27

July

5	.31
6	.015
7	.45
10	.33
22-23	1.50
25	.01
28	.015
31	.015

August

1	.05
2	.40
3	.39
4	.018
8	.40
9	.19
18	.02

September

11	.02
12	.05
13	.22
14	.24

Tables 2 and 3 give the well reading data for the various open fields on particular days during August and September, 1967. The water levels were low during the entire period which was a reflection of the low amount of rainfall. It is interesting to note that no change in water levels followed rains on August 2 and 8. The reason for this is that the unusually dry surface layers were able to absorb the rain that fell and so none reached the water table.

The data in Tables 4 and 5 also show low water table levels during July to September period. The wells in these areas are in a converging ditch system varying from very narrow ditch spacings to wide spacings. The cover was left natural on the surface of these areas so as to compare with the open cleared areas under cultivation.

Water levels in general are lower in the tree-covered converging ditch area than in the open fields. Many well readings in this system were consistently below 48 inches, which is actually about 24" of drained profile. This data shows that Sphagnum moss peat bogs can be adequately drained by ditching. The raised centers of the bogs allow for good ditch outlets.

Reference may be made to Figures 21 & 22 of this report where diagrams were presented showing the placement of the wells on the open fields as well as their locations on the converging system. Table 6 provides the key for determining the distance of the water tables below the field surface of the cultivated area.

Figure 32 depicts the rainfall -- water table relationship as measured at the center wells of the open fields for the 1967 season. The tremendous water storage capacity of the Sphagnum peat is apparent from the lack of effect on the curve of even an .8" rain (August 1 - 4). Again it must be remembered that the water table does not indicate the top level of saturation but the level of the free water for any given date. The rapid downward flow of moisture leaves the fields firm and with a good vehicle surface.

Figure 33 shows the cross section of each of the 5 open Sphagnum fields. The top line of each area (delineated by different crosshatching) denotes the surface across each field (numbered TWO, FIVE, FOUR, THREE) at the center. The bottom line of each crosshatched area is the water table as read on July 3, 1967. The ends of the crosshatched areas are the boundary ditches.

While it can be stated with certainty that the Sphagnum fields may be 25 feet wider than those of reed-sedge peat because of their greater storage capacity, it would be well for a producer

TABLE 2. PINE ISLAND WELL READINGS - AUGUST, 1967

Date	2	4	7	8	11	18	21	23	25	28	30
200D	39	39	38.5	38.5	38.5	38	39	39	39	39	39
201	35.5	36	36	36	36	36.5	37	37	37.5	38.5	38
202	31	32	33	33	33	34.5	35	35	35.5	35	36
203	27	28.5	28.5	28.5	29.5	30.5	31.5	31.5	32	32	33
204	26	27.5	28	28	28.5	30.5	31	31	31.5	32	32.5
205	26.5	27	27.5	27.5	28	30	30.5	30.5	31	31	32
206	25	26	26.5	26.5	27	28.5	29.5	30	29.5	30	31
207	27	28	28.5	28.5	29	30	30.5	30.5	31	31.5	32
208	32.5	33.5	34	34	34	35	36	36	35.5	36	37
209	36.5	37	37	37	37	37	37.5	37.5	37	38	39
209D	40	40	40	40	40	40	40.5	40.5	40	40.5	40
301	36.5	37.5	37.5	37.5	37.5	38	38.5	38.5	38.5	38	39
302	36	37	37	37	37.5	38.5	39	39	39	39	39.5
303	33	33.5	34	34	34.5	37.5	36	36.5	37	36.5	37.5
304	35	35.5	35.5	35.5	36	36.5	36.5	36.5	37	37	38
305	35	36.5	36.5	36.5	37	37	37.5	37.5	37	37.5	38
305D	40	40	40	40	40	40	40	40	40	40	40.5
400D	39	38.5	38.5	38.5	38.5	38	38.5	38.5	38.5	38.5	39
401	38	38.5	38	38	38	38	38.5	38.5	38.5	39	39
402	36.5	37.5	37.5	37.5	37.5	37.5	38	38	38	38.5	39
403	32	33	33	33	34	35	35.5	35.5	36	36	37
404	29.5	31.5	31.5	31.5	32	33.5	34.5	34.5	35	36.5	36
405	32	33	33	33	33	35	36	36	36	36	37
406	35.5	36.5	36.5	37	37	37.5	38	38	38	38	39
407	37.5	38	38	38	37.5	38.5	38.5	38.5	39	39	39.5
407D	39	39	39	39	39	38	38.5	39.5	39.5	39	40
501	37.5	38	38	38	38	38	38.5	38.5	38.5	38.5	39.5
502	31.5	32	33	33	33	34.5	35	35	35	35	36
503	28.5	29.5	30.5	30.5	31	32	33	33	33.5	34	34.5
504	26	27	27	27.5	28	29	30.5	30.5	30.5	31	32
505	25	26	26.5	26.5	27	28.5	29.5	30	30	30	31
506	26	27	27.5	27.5	28	29.5	30.5	30.5	31	31	32
507	29.5	30.5	31	31	31	32.5	33.5	33.5	33.5	34	35
508	31.5	32.5	33	33	33	34	34.5	34.5	34.5	34.5	35
509	36	36.5	36.5	36.5	37	37	37.5	37.5	37.5	37.5	38
509D	39	39	39	39	39	38.5	39	39	39	39	39

TABLE 3. PINE ISLAND WELL READINGS - SEPT., 1967

Date	1	6	8	11	13
200D	39	39.5	39.5	39	39
201	38	38.5	38.5	38.5	38
202	36	36.5	36.5	36.5	36
203	33	33.5	34	34	34
204	33	33.5	34	34	33.5
205	32	32.5	33	33	33
206	31.5	32	32	32.5	32
207	32.5	32.5	33	33	33
208	37	37	37	37.5	37
209	38.5	38	38.5	38.5	38
209D	41	40.5	41	41.5	40.5
301	39	39	39	39	39
302	39.5	40	40	40	39
303	37.5	38	38	38	38
304	38	37.5	38.5	38.5	38
305	38	38	38.5	38	38
305D	40.5	40.5	40.5	40.5	40.5
400D	39	39	39	39	39
401	39	39	39	39	39
402	39	39	39	39.5	39.5
403	37	37.5	37.5	37.5	37.5
404	36	37	37	37	37
405	37	37.5	38	37.5	37
406	39	39	39.5	39	39
407	39.5	39.5	39.5	39.5	39.5
407D	39	39	40	39.5	39
501	39.5	39	39.5	39.5	39.5
502	36.5	37	37	37	37
503	35	35	35.5	35.5	35.5
504	32	33	34	33	33
505	31	32	33	32	32
506	32	32.5	33	33	33
507	35	35	35.5	35.5	35.5
508	35.5	36	36	36	36
509	38.5	38	38	38.5	38
509D	39	39.5	39.5	39.5	38.5

TABLE 4. PINE ISLAND CONVERGING DITCH SYSTEM - JULY-AUG., 1967 WELL READINGS

	26	28	31	7	9	11	14	16	18	21	25	29	30
1D	46	46	46	46½	46½	46½	46½	46	46	46½	46½	45½	46
1	43	43	43½	44	44	44	44	43	43½	45	45	45½	46½
1D$_1$	46	46	46	46	46	46	46	46	46	46	46	46	46
2D	46½	46½	47	47	48½	48½	48½	46½	47	47	47	47	47
2A	56	56	56+	56	56+	56+	56+	56+	56+	56+	56+	56+	56+
2	46	46	46	47	47½	48½	48	46	46	50½	50½	51½	52½
2B	45	45	45½	43½	43½	43½	44	45	45½	44½	44½	45	45½
2D$_1$	43½	43½	44	44½	45	45	44½	43½	44	45	45	46½	47
3D	47	47	47	47	47	47	47	47	47	47½	47½	47	47
3A	45	45	46	46	46½	46½	46½	45	46	48	48	48	49
3B	39	39½	40½	41½	42½	42½	42½	39	40½	45½	47	47½	48
3	37	37½	38½	40½	40½	41½	41	37	38½	44	44½	46	46
3C	-	-	-	48	48½	48½	48	-	-	50	50½	51	51½
3E	48	48	48½	48½	49	49	49½	48	48½	49½	49½	50	50
3D$_1$	44	44	45	44½	45	45	44½	44	45	45	45	45½	45½
4D	59	59	60	59½	60	60	60½	58½	60	61½	61½	61½	61½
4A	44	44	45	46	46½	46½	47	44	45	49½	49½	50	51
4B	36	36½	37½	39	40	40	41½	36	37½	44	44½	45½	46
4	31	31	32	33½	34½	34½	35	31	32	39	39½	40½	41
4C	26	26	27	28	29	29	30	26	27	32	33	33	34
4E	38	38	38½	39½	39½	39½	40	38	38½	41	41	41½	42
4D$_1$	43	43	44	46	45	45	45	43	44	45½	45½	45	45½

TABLE 4. (Continued)

	26	28	31	7	9	11	14	16	18	21	25	29	30
5D	58	58	59	59½	59½	59½	59½	58	59	59	59	59	59
5A	- -	Frozen	- -	56+	56+	56+	56+	56+	56+	56+	56+	56+	56+
5B	49½	50	51½	52½	53½	53½	54	49½	51½	56	57½	57½+	57½+
5C	42½	43	44	45½	46½	46½	46	42½	44	50½	51	52	52½
5E	37	37	38	39½	40½	40½	41	37	38	45½	46	47½	47½
5	38	38½	39½	40½	41	41	41½	38	39½	46	46½	47½	47½
5F	42	42½	43½	45	45½	45½	46	42	45½	49½	50	51	51½
5H	40	40	40	41½	42	42	42½	40	40	45½	45	46½	46½
5J	34	34½	35½	36	36½	36½	37	34½	35½	38½	38½	39	39½
5D$_1$	43	43	44	41	41½	41½	41½	41	41	42	42	42	42
6D	55	55	56	55	55½	55½	55½	55	56	55½	55½	56	56
6A	54	57	65	56+	56+	56+	56+	54	55	56+	56+	56+	56+
6B	47	47	48	49	50	50	50½	47	48	52½	52½	54½	54
6C	36	36½	38	39½	40½	40½	41	36	38	44	44½	45½	46
6E	33	33½	35	36	37	37	37½	33	35	41	41½	43	43
6	34	34	35	36½	37½	37½	38	34	35	41½	42	43	44
6F	36	36	37	38	39½	39½	40	36	37	43	43½	45	45
6H	42½	43½	45	46½	47½	47½	48	42½	45	52	52	53	53½
6J	35	35	35	35	35½	35½	36	35	35	38	38	38½	39
6D$_1$	40½	40½	40½	40½	40½	40½	40½	40½	40½	41	41	42	42

TABLE 4. (Continued)

	26	28	31	7	9	11	14	16	18	21	25	29	30
7D	48	48	48	51	52	52	52	48½	48	51½	51½	51	51
7A	42	42	43	44½	44½	44½	44½	42	43	37	37½	48	49
7B	48½	35	27	28½	29	29	29½	28½	27	33½	34	35	36
7C	33	34	35	36	37	37	37½	33	35	41½	42	43	43
7E	33	33	33	34	35	35	35½	33	33	39	40	41	41½
7	36	35	32	33	34	34	34½	36	32	38	38	39½	39½
7F	22	22	23½	24½	25	25	26	22	23½	29	29½	31	32
7H	25	26	27	28½	29½	29½	30½	25	27	34	34½	35½	36
7J	34	34½	35½	37	37½	37½	38	34	35½	41½	42	43	43½
7K	36	36	36	36	36½	36½	37½	36	36	38	37½	38	38
$7D_1$	38	38	36	39	39	39	39	38	38	39½	40	40	40
8D	49	49	49	51	52	52	52	49	49	50½	50½	50	51
8A	48	48	49	50½	51½	51½	52	48	49	54	54½	55	55
8B	39	39½	41	42	43	43	43½	39	41	46½	47	48	48½
8C	31	31½	32½	33½	35	35	35	31	32½	38½	39	40	40½
8E	29	29	30	30	31	31	31½	29	30	34½	35	36	36½
8F	28	28	29	30	31	31	31½	28	29	34½	34½	38½	36
8	31	31	32	32½	33	33	33½	31	32	37½	37	39½	39
8H	30	30	31	31½	33	33	33½	30	31	37	37½	41½	39
8J	32	32	33	34½	35½	32½	34	32	33	40	40½	36	42
8K	26	26½	28	29½	30½	30½	31	26	28	35	35½	33½	36½
8L	27½	27½	28	29	29½	29½	30	27½	28	32½	33	33½	34
8M	33	33	34	34	34	34	34½	33	34	36	36	--	37
$8D_1$	35½	35½	36	36	37	37	37	35½	36	37	37	37	38

TABLE 5. PINE ISLAND CONVERGING DITCH SYSTEM.
WELL READINGS - SEPT., 1967

	6	8	11	14
1D	46½	47	47	46½
1	46	45½	45½	45
1D$_1$	46	46½	46	46½
2D	47½	47½	47	47
2A	Dry	Dry	Dry	Dry
2	52½	52½	53	53
2B	45	45	45	44½
2D$_1$	45	45	45	45
3D	47	47½	47½	47½
3A	49	49	49	49
3B	48	48½	49	49
3	47½	47½	48	48
3C	51½	51½	52	52
3E	50½	50½	48½	50
3D$_1$	45½	45½	50½	45
4D	61½	61½	61½	61½
4A	51½	51½	51½	51½
4B	47½	47½	48	48½
4	42	42	43	43
4C	34	34½	35	35
4E	42	42	42	42
4D$_1$	45½	45½	45½	45½

TABLE 5. (Continued)

	6	8	11	14
5D	59	59½	-	-
5A	Dry	Dry	Dry	Dry
5B	Dry	Dry	Dry	Dry
5C	53½	54	54	54½
5E	49½	50	50½	50
5	49½	49½	50	50½
5F	53	53	53½	54
5H	47½	48	48	48
5J	40	40½	40½	40
$5D_1$	43	42½	42½	42
6D	56	56	56	56½
6A	Dry	Dry	Dry	Dry
6B	55½	55	55½	55½
6C	47½	47½	48	48
6E	44½	45½	46	46
6	45½	46	46½	46½
6F	47	47	47½	48
6H	54½	55½	55	55½
6J	38½	39½	39½	39
$6D_1$	42	42	42½	41

TABLE 5. (Continued)

	6	8	11	14
7D	51½	51½	51½	51
7A	48½	48½	48½	48½
7B	37	37	37½	37½
7C	44	44½	46	45½
7E	43½	43½	44½	44
7	41	42	42	42
7F	33	33½	34	34
7H	37	38	39	39
7J	44	44½	45	45½
7K	39	39	39	38
$7D_1$	41	41	40½	39½
8D	51	51½	51½	51
8A	55½	56	56	56
8B	49	49½	50	50
8C	46½	42	43½	43
8E	38½	38½	39	39½
8F	38	38½	39	39
8	40½	40½	41	41½
8H	41	41½	42	41½
8J	43½	44	44	44½
8K	38	38½	39	38½
8L	34½	34½	35	34½
8M	37½	37½	37½	36½
$8D_1$	38	38	38½	37

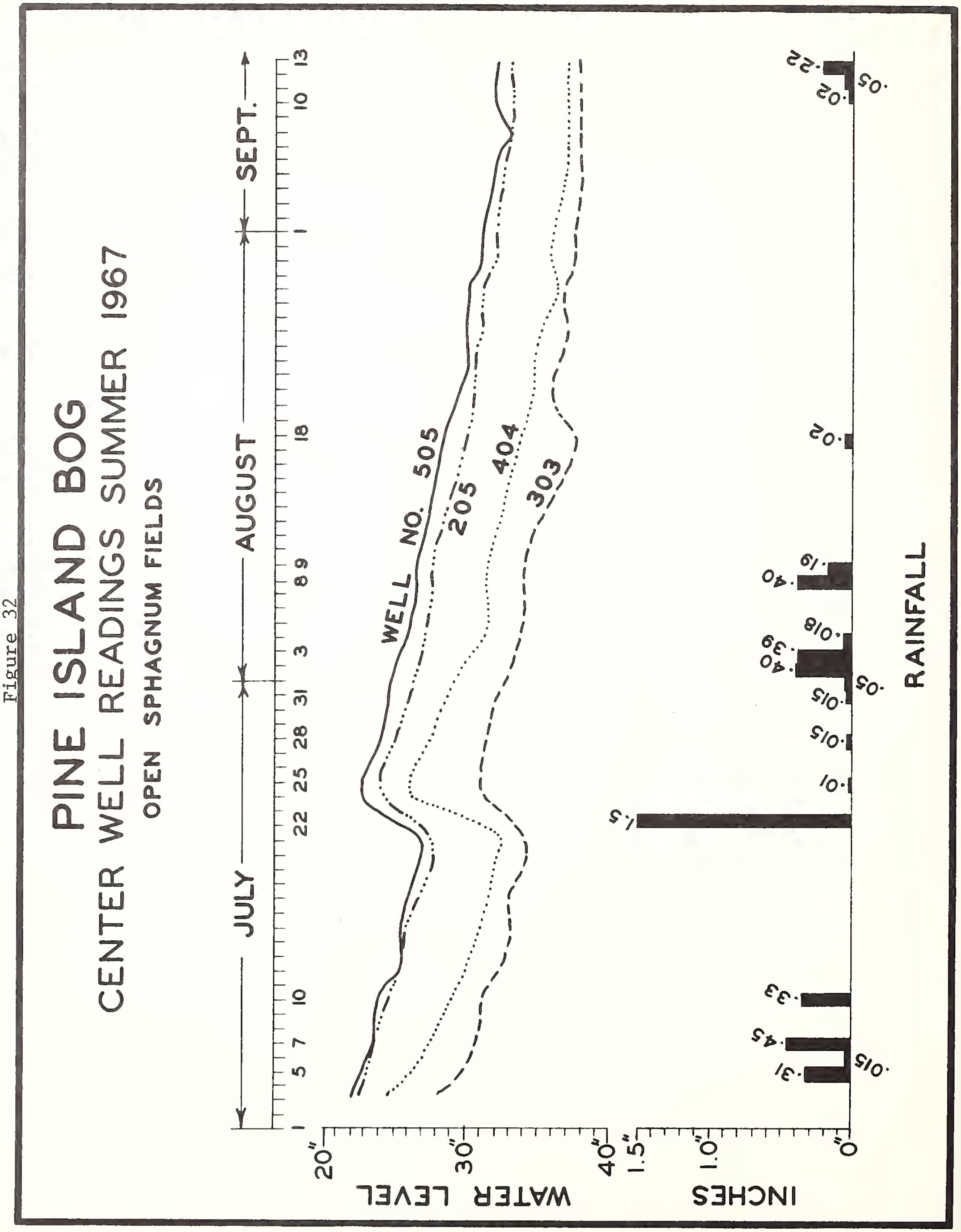
TABLE 6. PINE ISLAND WELL KEY FOR OPEN FIELDS

Subtract the height of the well above ground from the well reading to obtain the distance of water table below field surface.

HEIGHT OF WELL CASING PROTRUDING ABOVE PEAT SURFACE

Well #	Inches	Well #	Inches	Well #	Inches
200D	13	301	11	501	10
201	11	302	10	508	8
202	9	303	8	503	7
203	6	304	10	504	5½
204	5	305	9½	505	6½
205	5½	305D	13	506	8
206	5½	400D	17	507	8
207	5½	401	16	508	8
208	7½	402	12	509	12
209	9½	403	7	509D	13
209D	12	404	8		
		405	8½		
		406	9		
		407	12		
		407D	14		

Figure 32



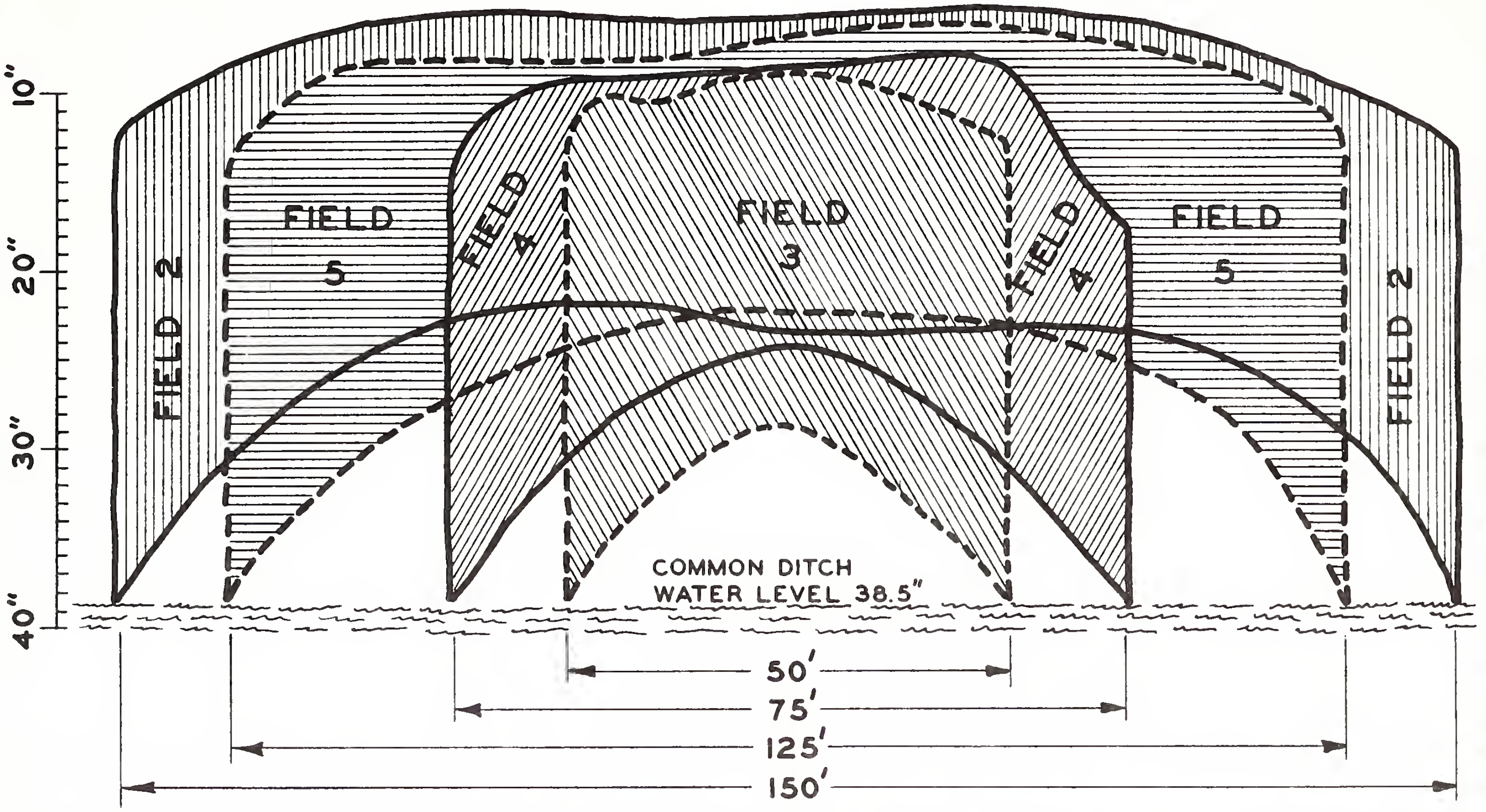
PINE ISLAND BOG
CENTER WELL READINGS SUMMER 1967
OPEN SPHAGNUM FIELDS

Figure 33

PINE ISLAND SPHAGNUM FIELDS

THE SHAPE OF THE PROFILE ABOVE THE WATER TABLE

JULY 3, 1967



NOTE: FIELD ENDS = DITCHES; TOP LINES = SURFACE; BASE LINES = H_2O TABLE to have several 75-foot fields to take care of emergency situations such as might occur in early spring or years of excessive rainfall.

3. A comparison of water table levels in drained and undrained bogs

During the summer of 1967 well readings of water levels in undrained bogs near the research facilities at Wilderness Valley Farms and the Pine Island Sphagnum moss bog were obtained as a comparison with those obtained in the drained fields. Tables 7 and 8 show this data.

The Pine Island facility wells were located about 1/8 of a mile east of the drained fields. The data was obtained at weekly intervals during the summer and the traverse or line of wells extended across the raised part of the Sphagnum bog (see Figure 34 for location) - The data shows that all of the water levels were relatively high when compared to the drained bogs. At the highest part of the raised bog or that portion with the greatest convexity (sites 19, 20 and 28) the water levels were lowest at all sampling dates except at well numbers 32 and 33 which were adjacent to a ditch. As the summer season progressed, water levels generally became lower and the lowest readings recorded were in September. (See Figure 35).

Contrast these well readings to those obtained during the same period in the open fields of the cleared and ditched areas with ditch spacings varying from 50 to 200 feet. Here the readings of the water levels were consistently 30 to 40 inches or more below the surface. This shows that drainage can be effectively obtained with proper ditch spacings and adequate outlets on these raised bogs.

Table 8 shows the water table levels in an adjacent undrained area of the Wilderness Valley Farms containing reed-sedge peat much the same in properties, thickness, etc. as that of the drained fields studied extensively over the past three years. The wells numbered PZW 1, 2, 3, and 4 were spaced 500 feet apart and oriented in the direction from which the water flows through the large bog area. Readings taken from August to November at weekly intervals are indicative of the wet condition of undrained bogs. All the levels were very near the surface of the bog except PZW-1 which was near a ditch. All others showed water levels averaging less than 8 inches from the bog surface during the season of the year when they should be at the lowest levels.

By contrast, the ditched fields were very effectively draining the bog at all spacings during this relatively dry period.

TABLE 7. PINE ISLAND WELL READINGS UNDRAINED BOG TRAVERSE - 1967

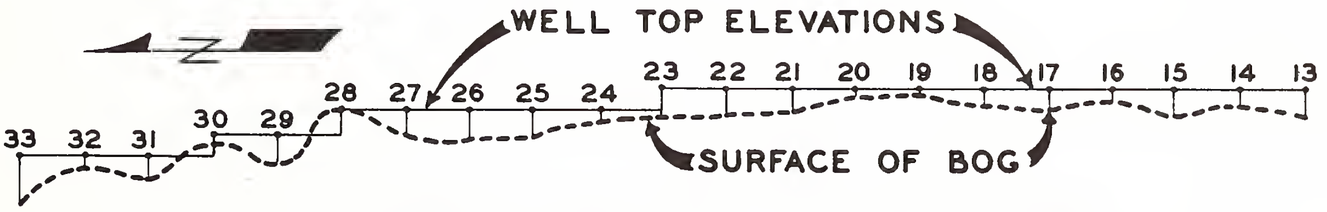
Well. No.	6/22	6/29	7/6	7/13	7/20	8/3	8/10	8/17	8/24	8/31	9/6	9/14
13	7.5	7.0	8.0	9.5	9.0	9.5	10.5	11.5	11.0	12.0	13.5	14.0
14	10.0	9.0	10.5	11.0	12.0	11.5	12.0	12.5	13.0	14.0	15.5	15.5
15	5.0	6.0	7.0	8.0	9.0	8.5	10.0	10.0	11.0	10.0	12.0	11.5
16	5.5	7.0	8.0	9.0	9.0	9.0	10.0	11.5	12.0	13.5	15.0	16.0
17	3.5	5.0	5.5	7.5	8.5	8.5	9.0	10.0	11.0	11.0	14.0	13.0
18	8.5	9.0	10.0	12.0	14.0	13.0	14.0	15.0	16.0	17.0	18.5	18.0
19	12.0	13.0	14.0	16.5	17.0	16.5	17.5	19.0	20.0	20.0	23.0	22.5
20	11.5	12.5	13.5	15.0	15.5	16.0	16.5	18.0	19.5	21.0	22.5	23.0
21	3.0	2.5	5.5	6.0	8.5	8.5	9.0	10.0	11.0	12.0	13.5	14.5
22	5.0	8.5	9.5	10.5	11.5	12.0	11.5	12.0	13.5	14.5	16.0	17.0
23	7.5	8.5	9.5	10.5	11.5	11.0	11.5	13.0	14.0	15.0	16.5	15.5
24	9.0	11.0	12.5	13.5	14.0	14.5	14.5	15.5	16.5	16.5	17.0	16.0
25	12.5	5.0	4.5	7.0	9.0	8.5	7.5.	9.0	10.0	10.5	12.5	12.5
26.	3.0	8.0	8.0	10.0	11.5	10.5	11.5	12.5	13.5	14.0	16.0	16.0
27	10.0	11.0	11.0	13.0	17.0	13.5	14.5	15.5	17.0	18.5	20.5	19.0
28	12.0	10.5	11.5	12.5	13.5	13.5	14.0	15.0	16.5	17.0	19.0	19.0
29	5.0	5.5	5.5	7.0	9.0	9.0	9.5	10.0	12.5	13.0	16.0	15.0
30	3.5	5.0	5.0	6.5	7.5	7.5	8.0	9.0	10.0	11.0	12.0	12.5
31.	7.5	8.5	10.5	12.0	12.0	12.0	12.0	14.0	15.0	17.0	18.0	18.0
32	18.0	18.0	18.5	19.0	20.5	19.5	21.0	23.0	24.0	26.5	29.0	28.5
33	5.0	0.0	0.0	12.5	17.0	12.0	16.5	20.0	24.0	24.0	24.0	24.0

Figure 34

PINE ISLAND

LAYOUT OF WELLS IN UNDRAINED BOG

(WATER LEVELS IN A VIRGIN BOG)



THE WELLS ARE SPACED 300 FEET APART

WELLS 31-33 ARE LEVEL WITH EACH OTHER;
29 & 30 ARE LEVEL BUT ON A LINE 13" ABOVE 31;
24-28 ARE LEVELED 15" ABOVE 29;
13-23 ARE 12" ABOVE 24.

DISTANCE BETWEEN WELL TOP & BOG SURFACE

STATION		STATION		STATION	
13	16"	20	3"	27	16"
14	10"	21	14"	28	0"
15	17"	22	16"	29	17"
16	8"	23	18"	30	6"
17	12"	24	7"	31	12"
18	10"	25	16"	32	9"
19	3"	26	18"	33	31"

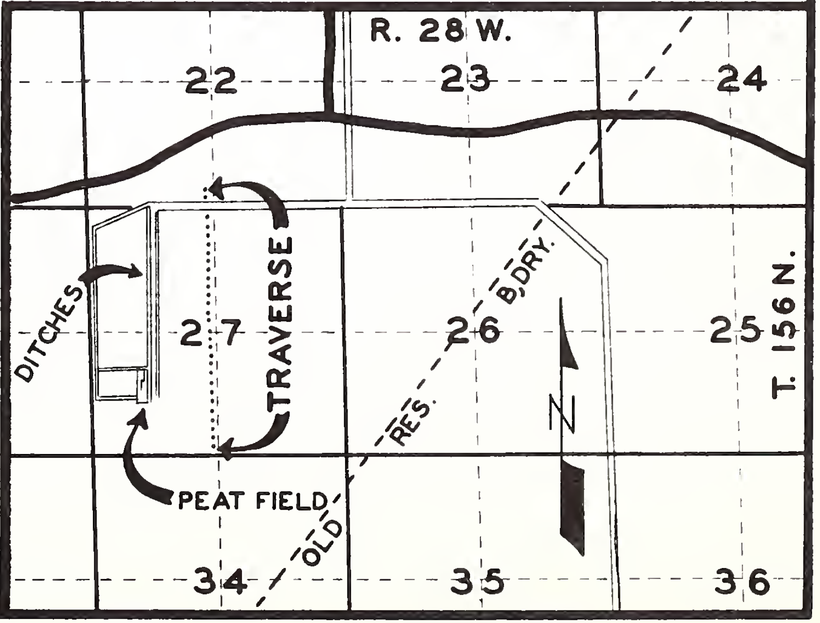
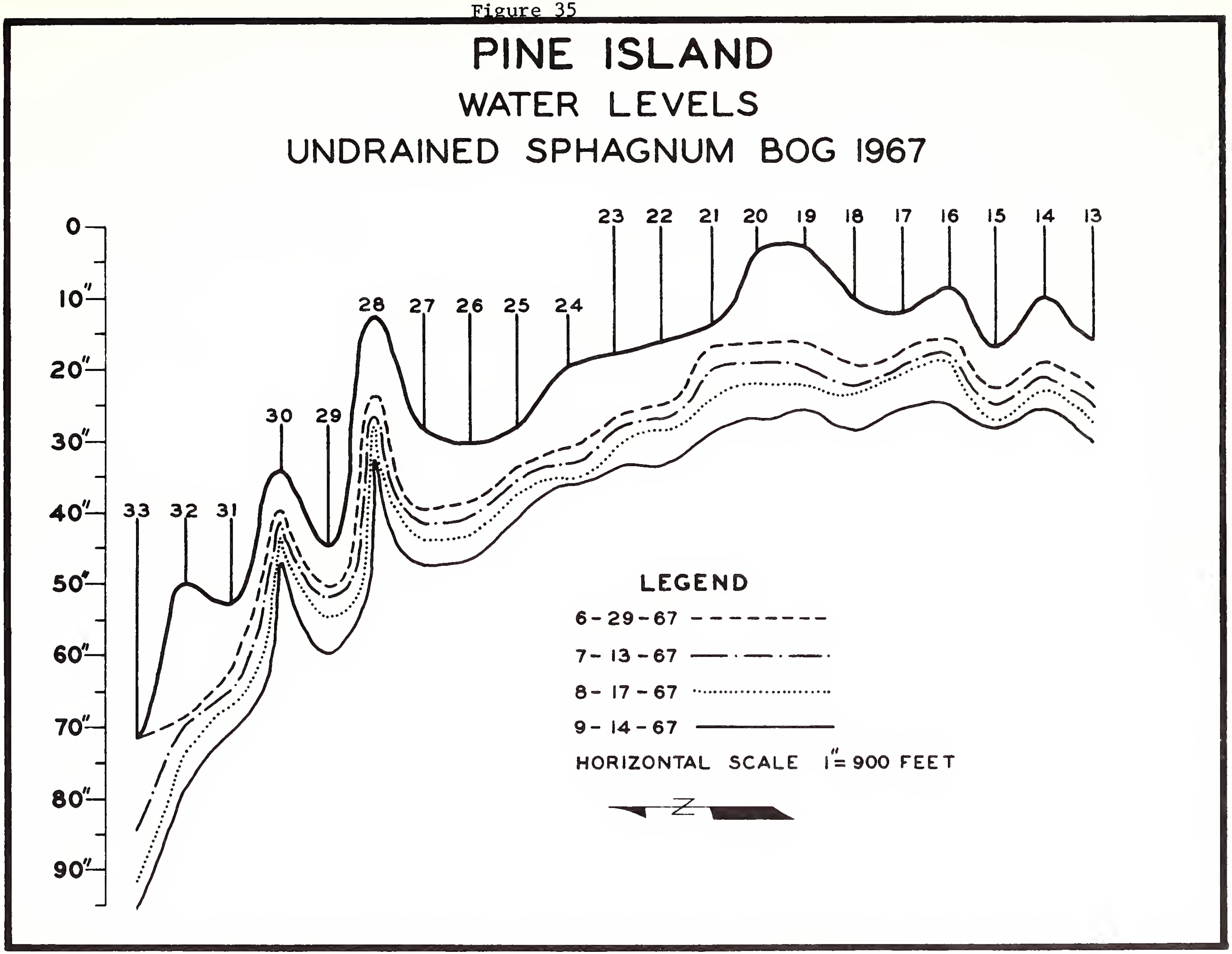


Figure 35



PINE ISLAND
WATER LEVELS
UNDRAINED SPHAGNUM BOG 1967

TABLE 8. WATER TABLE LEVELS IN UNDRAINED REED-SEDGE BOG (T. 55N, R. 18 W, St. Louis County)

1967

DISTANCE BELOW SOIL SURFACE OF WATER TABLE

Date	PZ-1	PZW-1	PZ-2	PZW-2	PZ-3	PZW-3	PZ-4	PZW-4
8/15	14.0	13.5	3.5	3.0	2.5	3.5	2.0	1.5
8/22	14.5	15.0	6.0	6.0	4.5	5.5	4.5	4.0
8/29	13.0	12.5	4.5	4.0	3.5	4.0	3.0	1.5
9/5	16.0	16.5	7.0	6.5	6.0	6.5	5.0	4.5
9/12	18.5	19.0	8.5	9.0	8.0	8.0	6.5	6.5
9/19	16.5	16.5	7.0	7.5	5.5	7.5	5.5	5.0
9/26	17.5	13.0	7.5	7.0	6.0	7.5	6.5	7.0
10/3	18.0	19.0	9.0	9.0	8.0	9.0	7.0	8.0
10/10	12.0	11.0	5.0	5.5	4.0	6.0	4.5	5.0
10/17	9.0	9.0	6.0	6.0	5.5	6.5	6.0	5.5
10/27	10/5	10.0	7.0	7.0	7.0	8.0	7.0	7.5
11/3	11.0	11.0	8.0	8.0	8.0	9.0	8.0	8.0

NOTE: PZ-(NO.) = A PIEZOMETER.
PZW-(NO.) - A COMPANION WELL.

The reliability of the perforated well as a means of locating the water levels in peat

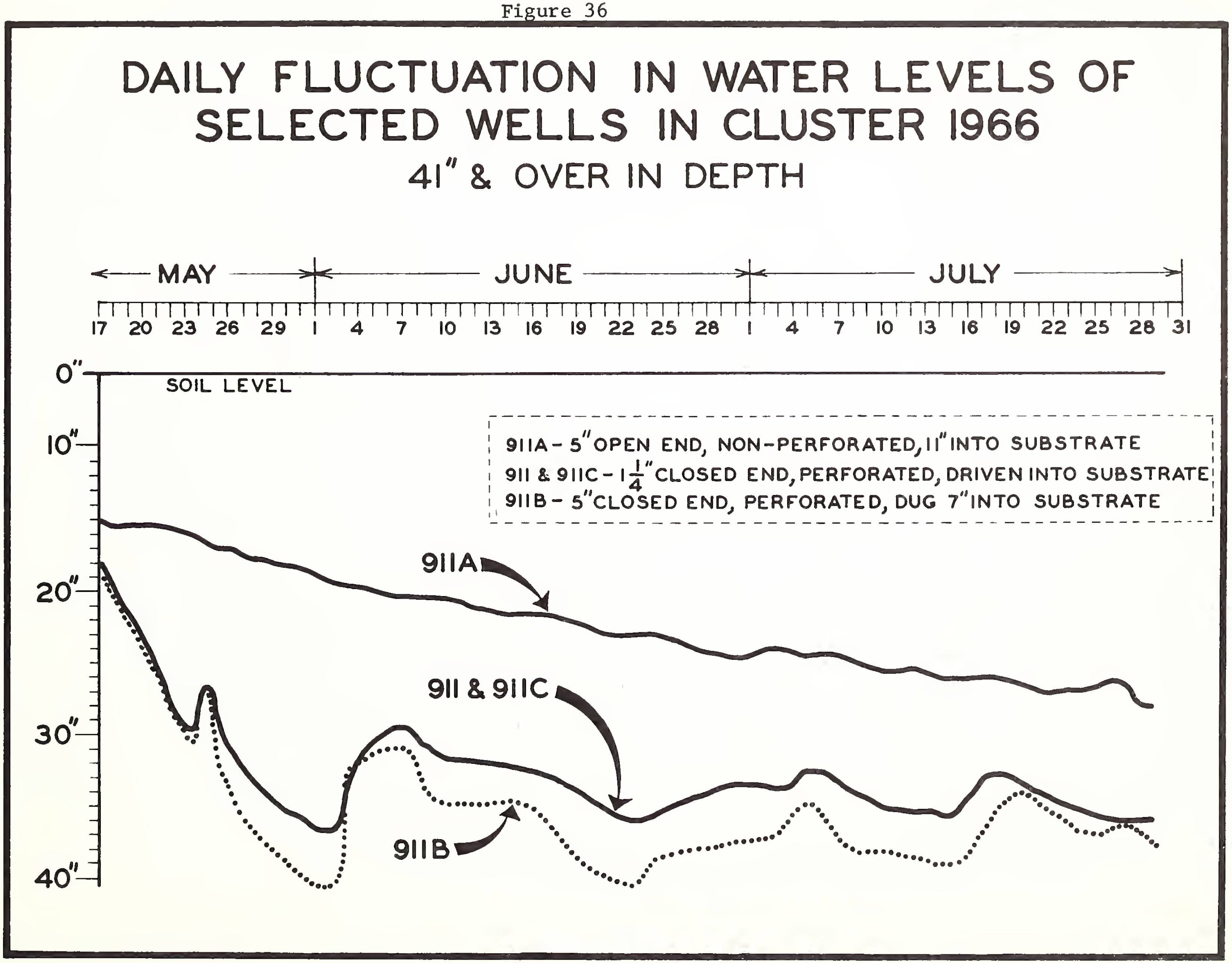
Since much of the work presented in this paper is inter-related with the water table in the peat, it was deemed advisable early in the study to determine the reliability of the well system. At benchmark No. 2 of field No. 9 a cluster of wells of various sizes and lengths were set in an area about 7 feet by 4 feet in size. (The layout is diagrammed and a detailed description of the experimental wells is given on pages 20 to 24 of this report.)

Five charts illustrating the data collected from this cluster are presented in proof of the accuracy of the wells. The "standard" well used in all the fields is a section 1¼ inch aluminum lightweight irrigation pipe, pinched shut at the bottom, perforated with ¼ inch holes from bottom to a point a bit below the soil surface. These are pushed and driven through the peat and into the substrate several inches. Thus they will vary from sections 3 to 7 feet in length. It was found advisable to cover the open end of the wells with a brightly painted can. The small baby food can serves very well. The identifying number of the well is painted on the can. In the cluster are wells of two diameters and three lengths with water entry from either the bottom only or sides only.

Let us look first at figures 36 and 37 which compare two diameters and two types of apertures. 911A and 911B are both of 5 inch diameter but "A" non-perforated. This well shows no variation with rains of any size because the movement of water in the substrate into which the open end is firmly set is very slow. In fact, the heavy rains of early August do not peak in this well until the first week in September. 911B shows for the first half of the season (Figure 36) a lower reading than do the wells of lesser diameter. It is our belief that this is because it takes longer for water to come from a greater area to fill the larger capacity of the 5 inch diameter than for the 1¼ inch pipe. This again seems to bear out when early August's heavy rains filled the soil, even the greater capacity of 911B was met quickly; later in the season when the table dropped sharply the lag of the early season was re-enacted. Wells 911 and 911C are identical "standard" wells and their readings throughout the season were identical.

A question arose especially after light rains as to how the well response could be so quick and fear was voiced that the moisture was funnelling in some of the surface holes. Three of the experimental wells definitely attested to the accuracy of the system. They were the non-perforated wells both 5 inch and 1¼ inch which did not enter the substrate --

Figure 36



DAILY FLUCTUATION IN WATER LEVELS OF SELECTED WELLS IN CLUSTER 1966

41" & OVER IN DEPTH

911A - 5" OPEN END, NON-PERFORATED, 11" INTO SUBSTRATE

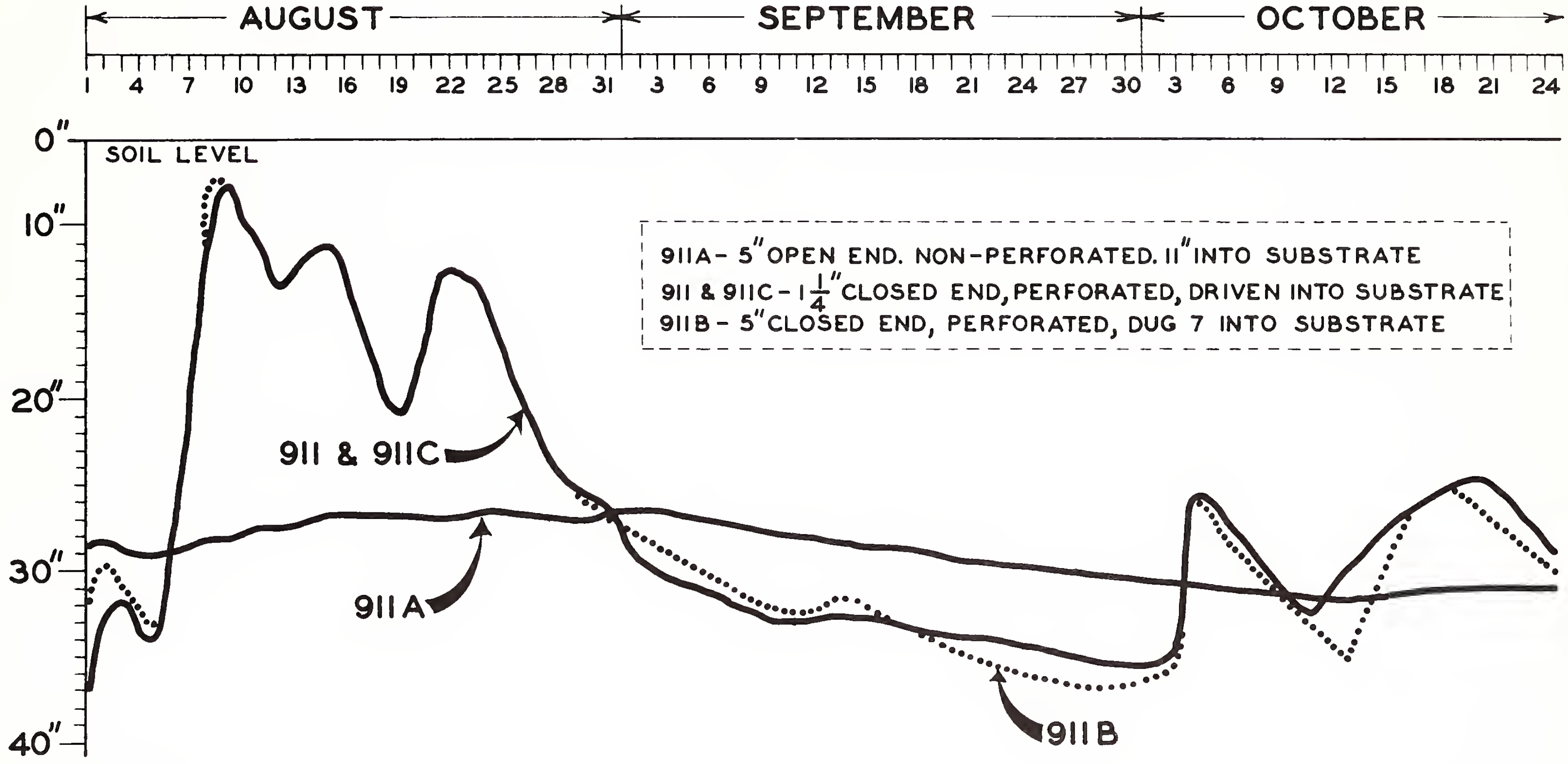
911 & 911C - 1$\frac{1}{4}$" CLOSED END, PERFORATED, DRIVEN INTO SUBSTRATE

911B - 5" CLOSED END, PERFORATED, DUG 7" INTO SUBSTRATE

Figure 37

DAILY FLUCTUATION IN WATER LEVELS OF SELECTED WELLS IN CLUSTER 1966

41" & OVER IN DEPTH



water simply percolated down through the peat and as the level rose in the body, it rose from the bottom up into these three wells. The rate of vertical water movements is very rapid in peat work done during 1967 to determine field capacity of peat bears this out.

Figure 38 compares the standard well with two $1\frac{1}{4}$ inch wells 41 inches long, one perforated and the other open only at the end. During the last half of the season the results were almost identical and indicate as long as the water table remained above the 35 inch well-reading, they were equally reliable. During the drier first half of the season, however, the two shorter wells tended to show lower readings as shown in Figure 39 .

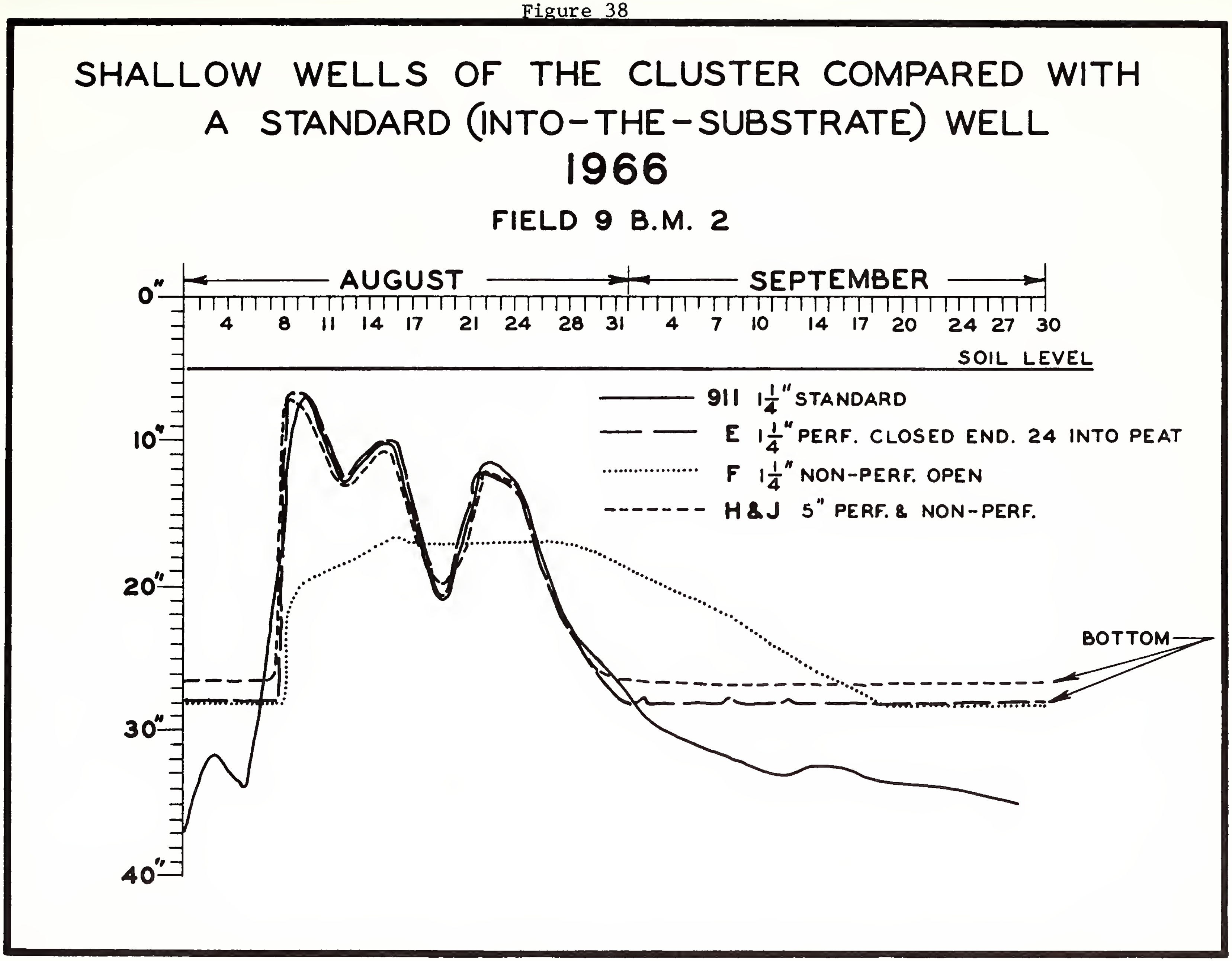
CONCLUSIONS: The well system as used in this study offers credible data and is eminently reliable as long as the same type of well is used throughout. Fears were allayed of soil leak to give higher readings than the existing level really is and satisfaction is enjoyed that hydrostatic pressure and meniscus-like abberations which were thought might confuse the readings with unpredictable variants proved unfounded. It was discovered, however, that most of the wells rise during the intermittent freezing and thawing of late fall and early spring and the system must be releveled for each season. There is also the constant danger of a knocking-out-of-level by the tillage machinery.

The term "water table" as applied to a peat bog is an unstable thing and as used in this paper denotes the level of the free water at any given time. It has no exact relationship to a demarcation line between saturated and unsaturated peat. Water is quickly taken into the pore spaces of the peat body. After a heavy rain the water table rises far higher than the volume of the precipitation as compared to the water storage capacity of the peat would indicate to be reasonable. The steady decline during the days which follow is both an inward and an outward drain. Inwardly water leaves the pore spaces and goes into the cell structure of the peat and outwardly it drains into the ditches. Hence we repeat, the water table of a bog as measured by the wells shows the level of the free water, the non-absorbed part, at the date of measuring.

4. Descriptions and basic data of peats studied

   a. Wilderness Valley Farms - Type: Reed-Sedge
      Location: NE$\frac{1}{4}$ NW$\frac{1}{4}$, Sec. 26, T. 55N, R. 18W, St. Louis County, Minn., $2\frac{1}{2}$ miles south of farm.
      Physiography: Large gently sloping glacial lake plain covered with peat.

Figure 38

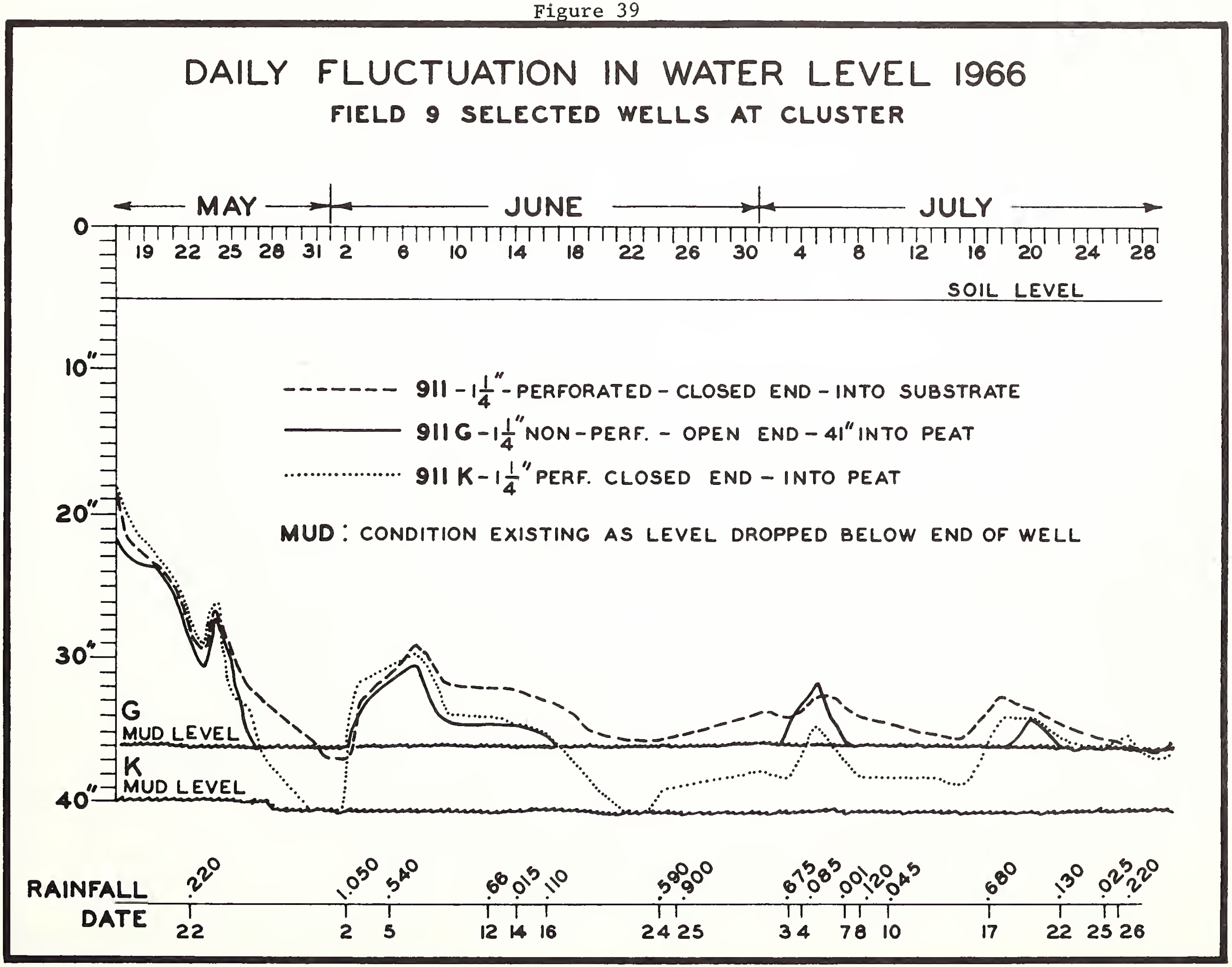


SHALLOW WELLS OF THE CLUSTER COMPARED WITH A STANDARD (INTO-THE-SUBSTRATE) WELL

1966

FIELD 9 B.M. 2

Figure 39

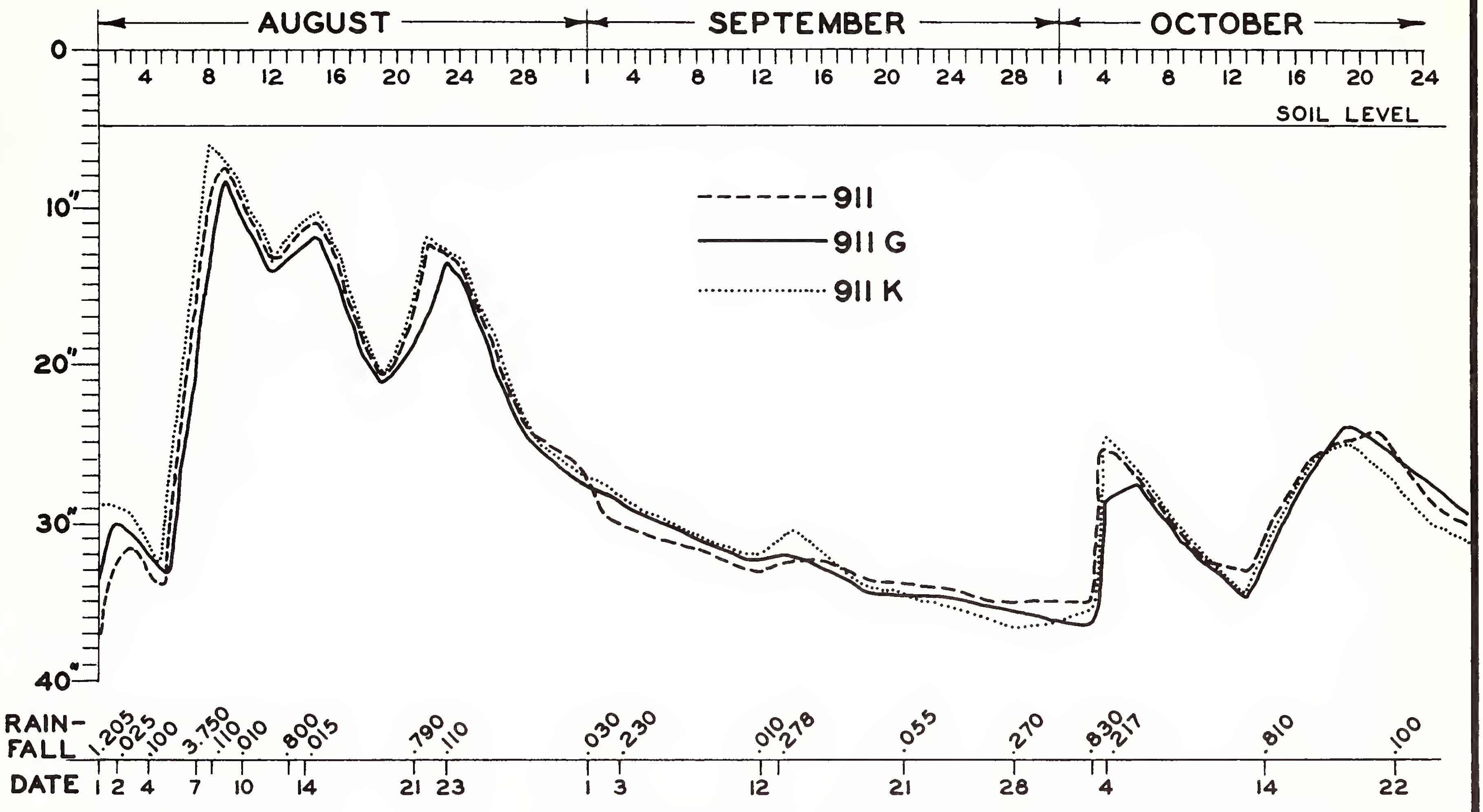


DAILY FLUCTUATION IN WATER LEVEL 1966
FIELD 9 SELECTED WELLS AT CLUSTER

Figure 39 cont.

DAILY FLUCTUATION IN WATER LEVEL 1966

FIELD 9-SELECTED WELLS AT CLUSTER



Relief: Bog slopes to southwest towards tributary stream of St. Louis River. Fall of 5 to 10 feet per mile average.

Native Vegetation: Mostly open sedge, grass, and reed bog with "islands" of tamarack, black spruce, or aspen in places.

Peat Profile Description -- 0-12 inches, partly decomposed reed-sedge-grass peat; fiber content 50-60%; very dark grayish brown color with black seams 1/2 to 1" thick.

12-60 inches, relatively undecomposed and uniform fibrous peat from reed; sedge and grasses; dark brown color with a few thin seams of black decomposed organic material; occasional roots and stems of tamarack; fiber content 80 to 90% of total mass.

60-72 inches, very dark gray partly decomposed to decomposed peat mostly derived from reeds and sedges; fiber content 35-40% of mass; few roots.

72 inches +, sandy clay loam, glacial drift and lake sediments.

ANALYSES

	pH	% Ash	% Water-Holding Cap.
0-12"	4.6	10.4	760
12-60"	4.5	7.5	900
60-72"	5.2	11.5	715
72"+	-	-	-

b. Meadowlands - Type: Decomposed Peat

Location: SW SW, Sec. 16, T. 53N, R. 18W, 4 miles east of Village of Meadowlands, St. Louis County, Minn.

Physiography: Gently sloping glacial lake plain near Whiteface River.

Relief: Bog slopes north and near river relief is 10 to 15 feet per mile providing excellent natural drainage.

Native Vegetation: Pure stand of white cedar (Thuga Occidentalis) averaging 6-8 inches in diameter and 25 feet high.

Description of Peat: 0-12" highly decomposed, black, peat with a few needles and wood particles of cedar; fiber content less than 20%; friable moist but compact in place.

12-48" decomposed, very dark gray to black, very friable peat with fiber content 20 to 30% mostly consisting of five wood particles.

48" + dark gray, fine sand lake sediments.

ANALYSES

	pH	% Ash	% Water-Holding Cap.
0-12"	5.5	15.5	580
12-48"	5.2-5.7	12.0	720
48" +	Fine sand	Lake Sediments	

c. Arlberg - Type: Sphagnum Moss Peat
Location: SW SW, Sec. 2, T. 51N, R. 19W, 9 miles east of Floodwood, St. Louis County, Minnesota.
Physiography: Isolated small inter-morainic glacial lake plain covered with peat located on a plateau-like position lying 80 to 100 feet above the present St. Louis River. This particular site is a part of a large (2 to 4 Square mile) raised bog which is elevated 5-8 feet above the surrounding peat-covered lake plain.
Relief: Raised (elevated) portion of peat plateau with relief of 5-10 feet per mile. Drainage of the entire area is in three directions - north to Spider Creek, west to a tributary of the St. Louis and south to St. Louis River proper.
Native Vegetation: Sphagnum moss peat understory in a pure black spruce (Picea-mariana) stand occupying the raised part of the bog. Associated acid plants growing on the sphagnum moss include leatherleaf, Labrador tea, and cotton grass.
Description of Peat: 0-6" live sphagnum moss hummocks with leatherleaf and Labrador tea.

6-12" sphagnum moss peat with thin seams of decomposed organic material; light brown to tan in color; highly acid.

12-72" reddish brown uniform sphagnum moss peat with very thin seams of decomposed organic material; some roots of black spruce and cotton grass; fiber content almost 100%; material lightens in color to a biege or light tan when squeezed; water is clear when squeezed; highly acid; fluffy fibrous peat with very low density.

72-180" partly decomposed dark brown reed-sedge peat containing tamarack roots; more dense than peat above and less acid.

180" + dark gray clay loam glacial till and lake sediments mixed.

ANALYSES

	pH	% Ash	% Water Holding Cap.
0-6"	3.8	7.2	1050
6-12"	3.5	4.1	1506
12-72"	3.4	2.5	1780
72-180"	4.4-5.5	5.0-11.2	650-900
180 +	Clay loam	Glacial drift	

d. Basic data - Volume-weight relationships

(1) Small core samples (Oven dry volume weight) (320 cc volume samples)

(a) Reed-sedge peat - Wilderness Farms - Sec. 26
.19 gms/cc or 11.85 lbs. /cu. ft.
.16 gm/cc or 10.58 lbs./cu. ft.
.17 gm/cc or 10.61 lbs./cu. ft.

(b) Sphagnum moss peat - Arlberg
.06 gms/cc or 3.74 lbs./cu. ft.
.07 gms/cc or 4.37 lbs./cu. ft.
.09 gms/cc or 5.61 lbs./cu. ft.
.06 gms/cc or 3.74 lbs./cu. ft.
.07 gms/cc or 4.37 lbs./cu. ft.

(c) Decomposed peat - Meadowlands
.25 gm/cc or 15.6 lbs./cu. ft.
.26 gm/cc or 16.2 lbs./cu. ft.
.23 gm/cc or 14.4 lbs./cu. ft.

(2) Large (Cubic Foot) Volume Samples

(a) Reed-Sedge Peat - Wilderness Valley Farms Basic Area
Volume of Sample: 1 cu. ft.
Weight (Field Moist): 60.75 lbs.
Water Content (Field Moist): 79.7%
  Weight of Water/cu. ft.: 48.4 lbs. water
  Weight Oven Dry Peat/cu. ft.: 12.35 lbs.
Volume of Shredded Sample (moist): 1.9 cu. ft.
  Weight/cu. ft. of shredded sample (moist): 31.0 lbs.
  Weight/cu. ft. of shredded sample (oven dry): 6.2 lbs.

(b) Sphagnum Moss Peat - Arlberg
Volume of sample: 1 cu. ft.
Weight (field moist)/cu. ft.: 52.3 lbs.
Water content (field moist): 90.3%
Weight of water/cu. ft.: 47.2 lbs.
Weight of oven dry peat/cu. ft.: 5.1 lbs.
Volume of shredded peat (moist): 1.8 cu. ft.
Weight/cu. ft. of shredded sample: 29.0 (moist)
weight/cu. ft. of shredded sample (oven dry): 2.9 lbs.

(c) Sphagnum Moss (Top Moss) - Pine Island, Koochiching County
Volume of sample: 1 cu. ft.
Weight field moist: 38.0 lbs.
Water content (field moist): 88.6%
Weight of water/cu. ft. (moist): 33.6 lbs.
Weight of oven dry peat/cu. ft.: 4.4 lbs.
Volume of shredded peat moist: 2.0 cu. ft.
Weight/cu. ft. of shredded sample (moist): 19.0 lbs.
Weight/cu. ft. of shredded sample (oven dry): 2.2 lbs.

(d) Decomposed Peat - Meadowlands
Volume of sample: 1 cu. ft.
Weight field moist: 57.0 lbs.
Water content (field moist): 77.2%
Weight of water/cu. ft. (moist): 44.0 lbs.
Weight of oven dry peat/cu. ft.: 13.0 lbs.
Volume of shredded peat moist: 1.7 cu. ft.
Weight/cu. ft. of shredded peat (moist): 33.5 lbs.
Weight/cu. ft. of shredded peat (oven dry): 7.6 lbs.

5. Field drying experiments

A considerable amount of time was spent in the early season of 1966 perfecting a sampling technique which would introduce minimum error and make the results reliably comparable day after day. The methods finally arrived at involved the use of a 6-inch length of 5-inch aluminum tubing, the walls of the bottom end filed to a sharp edge, and the outside graduated in 1/2 and 1 inch bands to measure depth of penetration. In use, the cylinder was set 1/2 inch into the surface to be sampled and a thin but rigid sheet of stainless steel was slipped under, slicing the sample from the surrounding and underlying soil. Considerable care had to be taken to prevent clods and sticks from being pulled into the sample. Ten samplings were combined from each field preparation and placed into a marked poly bag and taken back to the lab where the sample was thoroughly mixed

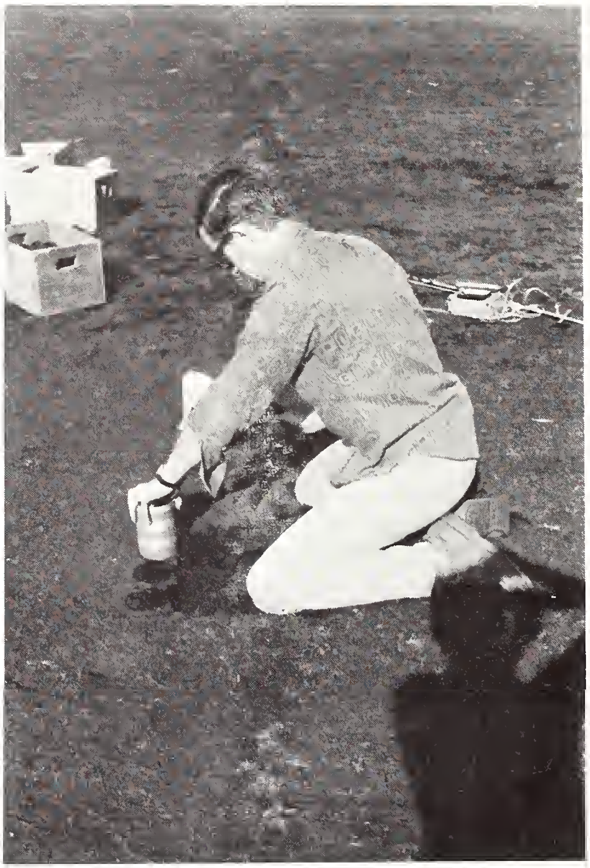


Fig. 40. Sampling the surface of an untreated area. The cylindrical "cookie" cutter is pressed 1/2" into the surface and then a thin but stiff metal sheet is slid under to cut the sample loose. 5 - 10 samples were combined from which a composite was taken in the laboratory for moisture determination.

and resampled for the oven.

Soil preparations in 1966 involved the most commonly used field equipment: a tandem field disk, a spike-toothed harrow (or drag) and a rotary hoe. Two other samplings were often made: the untreated area and a strip which had been disked and then immediately rolled flat with a 30" field packer.

The treatments were usually made early in the morning (between 8 and 9 a.m.) and samplings made immediately and at 2 or 3 hour intervals until 4:30 or 5:00 p.m. The treatments were made at one side or another of B.M.'s 1, 2, and 3 on field No. 9 only. After the field had been sampled it would be roto hoed and rolled to refirm it and to control the grass and wild plants which quickly sprang up on the perfect seed bed. Then the treatments would be conducted over again. This in reality does not vary much from the actual method of field preparation commonly used with operations involving flail or vacuum harvesters. The fields being stirred over and over again in preparation for going over and over them with the pickup machines.

There are many variables which affect the drying rate:

a. The size of the particle.
b. The increase in soil surface.
c. The interruption of capillary action.
d. Depth of soil treatment.
e. The air temperature.
f. The sun's intensity.
g. The wind speed.
h. The humidity.

Our facility was hardly sophisticated enough to separate each factor and properly evaluate it. However, from such data and personal observations as we obtained, the following statements are presented.

a. The smaller particle sizes yielded the driest peat. The rotary hoe and drag consistently provided the most pulverized surface. No method to determine yield experimentally was devised so this statement is based only upon the observations made by the authors in visits to commercial fields. The disk tended to leave the surface rough and cloddy and clods lost little moisture in one day of drying even on the hottest days.
b. The rougher the soil surface the greater the amount exposed. An ideal situation would be one in which the finely pulverized surface might be ridged. The disk left the greatest amount of peat exposed but did not leave it in small particles.
c. The interruption of capillary action is, of course, best

achieved in a finely divided soil -- cloddy soil simply moves the moisture from the centers out, which may well be too far to thoroughly dry in the harvest day; this break need only be but a fraction of an inch below the surface. No piece of equipment which we possessed would adjust to this shallow penetration. The 1967 drying experiments delt primarily only with shallow stirring of the surface.

The treatment of disking and immediately rolling simply re-established capillarity and in all cases offered no aid to drying. It is a well established practice in setting vegetable transplants on peat soils to roll immediately ahead of the planter to "bring the moisture up" to the newly set plants.

The following table indicates the type of readings consistently obtained by these treatments.

8-29-66 Field No. 9 B.M. 2 Well No. 910 25"

Treatment	Sample Time			
Sampled at 1/2" Depth	8:30	10:30	2:40	5:00
Rotary Hoe	75.0	72.4	64.6	63.2
Spike Harrow	75.0	71.8	66.5	65.9
Disk & Roll	75.7	75.2	73.3	72.0

The deeper the treatment extended the more difficult was the job of drying. The following chart indicates this fact.

MOISTURE AT VARYING DEPTHS (PERCENT)

Sample Date	Field	0"-½"	½"-1½"	1½"-2½"	2½"-3½"	3½"-4½"
8-11-67	9	73.57	73.71	73.74	74.35	77.65
8-16-67	8c	62.81	68.77	70.27	71.15	76.04
8-22-67	8c	61.92	69.04	71.36	74.10	74.77
9-1-67	7w	60.19	68.95	70.15	73.28	75.57
9-5-67	8c	51.89	66.89	69.32	69.98	73.83
9-6-67	8c	48.27	66.38	69.29	70.43	72.62

It could not be otherwise than when a 4-inch layer is thoroughly mixed that the resulting moisture level of the whole will exceed the top 1/2 inch by a considerable amount - and this 1/2 inch is all that the harvester will need to remove on the average drying day anyway.

Air temperature, solar intensity, and wind velocity -- These factors seem closely related and no method of determining the importance of any one was devised, in fact, we have only some observations to offer.

It was not uncommon for the air temperature on a windy day to be relatively low and still the soil temperature was high. There have been very hot days with low wind speed in which, though the soil becomes quite hot, the drying was slow. However, windy warm days with overcast skies do not result in the best drying. It should simply be remembered that the wetter the soil is the greater amount of heat will be needed to convert it to vapor. It should also be remembered that the wetter the peat soil, the darker its color and the greater the amount of energy 'adsorbed'. This is probably why the disked, and disked and rolled surfaces often showed the highest surface temperatures on hot days. When a thin layer of the peat becomes dry it becomes a very efficient insulator against heat entering and hence, moisture leaving. So it seems there is little reason for attempting to dry more than a ½ inch depth before removing it with the harvester.

The relationship of humidity to the drying of the peat presents a problem complicated by many things. Certainly the temperature with its effect upon the air's capacity to carry vapor and the speed of the wind to bear it away are also closely related. The answer is probably of only academic value as regarding conventional harvest systems, but no doubt is basic to a serious consideration of using solariums to step up the drying rate.

The results of the drying trials conducted show quite conclusively that the depth of harvesting, size and slopes of particles, the amount of wind, the temperature, etc. affect rate of drying.

Field drying experiments -- Much data was obtained during this period on drying of peat in the fields at several locations to determine the most efficient method. Variables include depth of sampling, time of day, temperature, water table levels, and various field preparation techniques. A total of 640 samples for water content were collected and analyzed during the two months. However, only two representative days were chosen to show the kinds of data obtained. We chose an average summer day with temperatures ranging from 55 degrees to 79 degrees as one typical day for data presentation (Tables 9 and 10), and another day with much above normal temperatures as an example of what can be expected on a very hot day (Tables 11 and 12).

The data shown in Tables 9 and 10 for July 20, 1966 is approximately average for this time of year in Northern Minnesota. Field preparation prior to sampling in these

TABLE 9. FIELD DRYING EXPERIMENT - FIELD NO. 9 (B.M. 2) RATE OF DRYING AS AFFECTED BY DEPTHS, TIME OF DAY AND PREPARATION PROCEDURE

JULY 20, 1966 (AVERAGE SUMMER DAY

Percent Water By Preparations

Time of day	Drying time (hrs.)	Rotary Hoe		Dragged		Disked		Disk & Roll		Untreated	
		½"	1"	½"	1"	½"	1"	½"	1"	½"	1"
8:15	0	63.6	67.8	65.8	63.0	68.9	69.2	69.2	69.4	58.9	64.7
10:30	2	60.5	60.4	57.5	60.3	66.1	68.2	66.0	68.2	57.8	60.8
12:30	4	55.4	59.2	58.9	56.4	62.7	63.9	64.5	67.3	51.7	54.5
14:30	6	53.2	58.6	54.3	58.2	62.1	61.2	62.5	64.6	58.5	61.2
16:30	8	47.3	52.7	50.0	57.6	61.0	62.0	63.9	62.0	54.7	60.0

TABLE 10. TEMPERATURES (DEGREES F) FOR FIELD NO. 9 (B.M. TWO)

July 20, 1966

	Time of Day				
	8:15	10:30	12:30	14:30	16:30
Weather Station (shaded)	55°	68°	74°	76°	79°
Untreated Surface	-	93	112	110	103
½ "	-	73	82	85	85
1"	-	72	80	85	83
2 "	-	65	73	78	79
3 "	-	62	67	72	74
4 "	-	61	64	67	69
Disk and roll					
½ "	-	75	82	84	82
1 "	-	74	80	80	80
2 "	-	64	71	75	76
3 "	-	63	68	72	73
4 "	-	62	64	68	70
Disk					
½ "	-	74	85	85	83
1 "	-	73	78	81	79
2 "	-	67	75	80	80
4 "	-	62	65	70	72

TABLE 11. FIELD DRYING EXPERIMENT - FIELD NO. 9 (B.M. THREE) RATE OF DRYING AS AFFECTED BY DEPTH, TIME OF DAY, AND PREPARATION PROCEDURE. JULY 8, 1966 (MUCH ABOVE AVERAGE TEMPERATURE.)

Percent Water by Preparations

Time of day	Drying time (hrs.)	Rotary Hoe		Dragged		Disked		Disk & Roll		Untreated	
		½"	1"	½"	1"	½"	1"	½"	1"	½"	1"
8:30	0	51.2	55.3	55.2	61.3	68.7	69.0	66.4	68.4	50.0	61.3
10:30	2	58.6	57.8	59.7	53.1	65.0	61.8	65.9	62.8	59.3	62.0
12:30	4	47.8	56.2	54.5	49.7	56.3	60.8	59.2	61.1	54.4	61.8
14:30	6	41.4	50.2	40.1	51.0	57.7	58.0	56.2	57.3	56.3	61.3
16:30	8	33.5	43.0	44.2	51.4	50.3	56.2	46.3	58.5	28.9	43.3

TABLE 12. TEMPERATURES (DEGREES F) JULY 8, 1966 FOR VARIOUS SURFACES FIELD NO. 9 (B.M. 3)

Field Temperatures

Depth	Untreated	Rotary Hoe	Dragged	Disk	Disk & Roll
	14:45	15:00	15:15	15:30	15:30
Surface	115 °	115 °	115 °	120 °	120 °
½"	92	94	100	98	90
1"	86	90	87	88	86
2"	77	78	80	80	79
4"	71	71	70	71	70

Weather Station (shaded)

8:30	66 °
10:30	78 °
12:30	82 °
14:30	86 °
16:30	90 °

experiments included the rotary hoe, spiked tooth drag, disk, and disk and roll. One area was left untreated or relatively undistributed. Sampling depths were 1/2 inch and 1 inch below the surface. Intervals of time between samplings were two hours and total drying time each day was 8 hours.

The data in both tables show that the best preparation to be the rotary hoe. The shallower sampling depth (1/2 inch) produced the driest peat. The drier peat resulting from shallower sampling were expected but differences between preparation procedures at this shallow depth were more varied than anticipated. Preparation of fields to achieve minimum bulk density or maximum fluffiness of peat by mechanical means seems to be one of the most important harvesting techniques in the peat industry (See Table 11). From data obtained in 1967 it would seem that this method of harvesting needs to be re-evaluated by peat harvesters.

Since an abundance of data was collected during the summer of 1966, most of the field drying data collected in 1967 was related to the two new methods of stirring - hand raking and rototilling. Samples included both those from the open field and samples taken from beneath a solarium (small, low, "greenhouse-like", poly-covered shelter). This data is presented as Tables 14 to 23 .

Several interesting observations become evident as the data is studied.

a. The undisturbed areas (roto-hoed and then rolled and in many cases it had been rained upon giving a smooth, felted, unbroken surface) dried very little. In fact, there was a rapid uptake of moisture in this 1/2" layer lying in unbroken position with the substrates capillary system everytime the sun went under a cloud.
b. The raked areas were prepared with a garden rake only penetrating the surface 1/2" to 3/4" and simply breaking up the surface crust and disrupting the capillary system. Since the soil was not disturbed in the wetter zone below only moisture in the 1/2" harvest zone was affected.
c. The consistently poor showing of the tilled areas simply supports the observations of 1966 that it is unnecessary to stir the harvest field below the 1/2" level.
d. The poor showing of the solarium may indicate two things: (1) that a considerably larger area of air needs to be trapped than the 10 x 12 x 3 foot high area used in this trial, and (2) that a fan is necessary to move the warm water laden air out of the solarium. The one time it worked fairly well was a very hot and windy day.

TABLE 13. DATA ON PEAT PROFILES - BASIC AREA JULY 12, 1966

Depth(inches) (inclusive)	Water Wet Weight %	Temp.* (F)	Vol. Weight lbs./cu. ft. dry	lbs.water/ cu. ft.
2-4 "	80.8	67.5°	10.6	44.6
5-7 "	82.3	64.7	10.0	46.5
8-10 "	83.9	62.0	9.4	49.0
11-13"	84.8	60.0	9.4	52.4
14-16"	86.0	59.0	8.1	49.7
17-19"	86.4	57.3	7.5	47.7
20-22"	87.3	55.0	7.5	51.5
23-25"	87.2	52.5	7.8	53.1
26-28"	87.3	50.7	7.8	53.6
29-31"	86.9	49.5	7.9	52.4
32-34"	86.9	48.2	7.9	52.4

* Temps below 34" remain 46 degrees (F)

Water table at 34 inches.

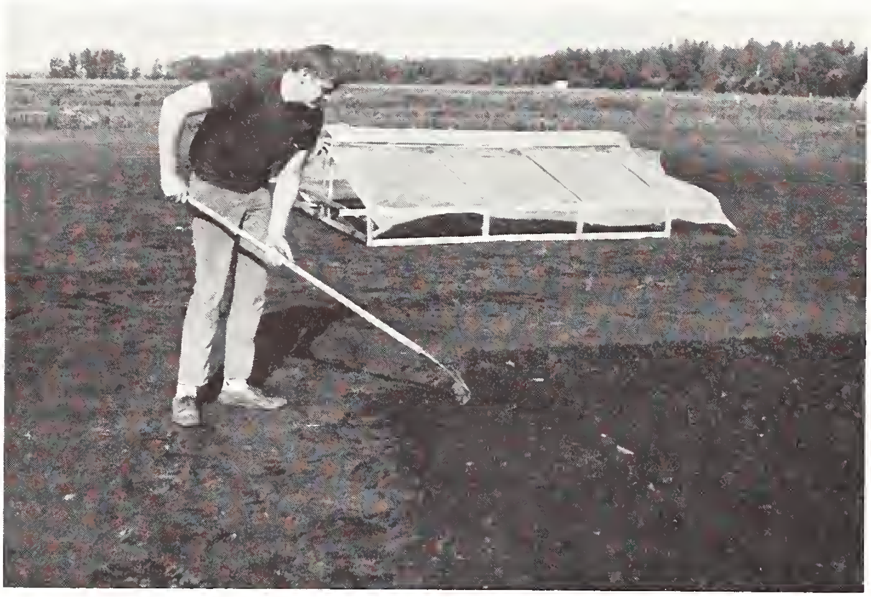


Fig. 41. Surface drying experiments in 1967 majored in shallow stirring. Shallow foot impressions where the boy stands indicates firmness of the field. The solarium used is in the background. Side ends and vented apex allowed ready exchange of air. Raking, as in the above picture, penetrated only about 1/2".

TABLE 14. RATE OF DRYING IN 10 SELECTED SITES COMPARING UNDISTURBED AND RAKED SURFACES 7-27-67 TO DEPTH OF 1/2"

Location	Treatment	% Moisture (Wet Weight)				Water Table
		9:00	11:00	1:15	3:25	
904	Undisturbed	75.61	74.96	75.78	74.50	20"
904	Raked	75.06	74.25	72.95	70.89	"
		9:30	11:30	1:45	3:30	
907	Undisturbed	74.75	74.60	74.00	73.50	22
907	Raked	79.53	71.22	70.06	66.15	"
		9:40	11:40	1:40	3:25	
1004	Undisturbed	76.17	76.62	77.18	76.22	19
1004	Raked	77.07	75.76	76.58	74.57	"
		9:55	11:55	2:00	4:00	
911	Undisturbed	76.68	75.97	76.32	75.61	17½
911	Raked	76.58	75.76	75.22	73.74	"
		10:10	12:10	2:10	4:10	
914	Undisturbed	73.07	71.89	72.49	71.88	22½
914	Raked	73.14	72.41	67.26	67.05	"
		10:15	12:15	2:15	4:15	
921	Undisturbed	73.00	72.80	73.12	72.48	25
921	Raked	72.84	70.29	66.51	66.79	"
		10:30	12:30	2:30	4:25	
918	Undisturbed	74.97	74.95	74.78	73.06	17½
918	Raked	74.74	72.58	72.25	74.38	"
		10:35	12:35	2:40	4:40	
8E5	Undisturbed	73.54	72.52	72.75	73.23	24½
8E5	Raked	72.93	70.52	67.45	64.52	"
		10:50	12:50	2:55	4:50	
7E8	Undisturbed	73.21	69.34	72.75	71.66	23½
7E8	Raked	73.39	72.07	66.81	64.14	"
		11:00	1:00	3:10	5:05	
6W	Undisturbed	77.10	76.29	77.30	72.51	22
6W	Raked	76.25	72.55	69.14	67.15	"

TABLE 15. RATE OF DRYING IN 5 SELECTED SITES COMPARING UNDISTURBED AND RAKED SURFACES TO DEPTH OF 1/2" - July 28, 1967

Location	Treatment	% Moisture (Wet Weight)				Water Table (Inches)
		9:30	11:30	1:30	3:20	
911	Undisturbed	74.99	74.68	74.49	74.48	20½
911	Raked	76.61	73.81	74.07	73.02	"
		9:45	11:40	1:40	3:30	
914	Undisturbed	72.13	71.88	71.20	71.67	26
914	Raked	70.92	67.78	66.80	63.84	"
		10:05	12:00	1:05	3:45	
1014	Undisturbed	76.16	75.76	75.34	74.92	20
1014	Raked	76.29	73.54	71.32	71.00	"
		10:30	12:15	2:20	4:00	
8E5	Undisturbed	70.84	71.32	71.40	70.86	28
8E5	Raked	71.00	67.76	67.87	61.64	"
		10:50	12:35	3:40	4:10	
7E8	Undisturbed	72.19	72.45	71.81	71.37	26
7E8	Raked	70.63	68.05	64.24	64.33	"

TABLE 16. RATE OF DRYING IN 6 SELECTED SITES TO DEPTH OF 1/2" COMPARING UNDISTURBED AND RAKED SURFACES - AUGUST 2, 1967

Location	Treatment	% Moisture (Wet Weight)				Water Table (Inches)
		9:25	11:20	1:15	3:10	
901	Undisturbed	72.78	72.53	71.92	71.23	30
901	Raked	73.06	70.90	67.57	66.37	"
		9:45	11:40	1:35	3:30	
904	Undisturbed	74.96	74.44	73.93	73.72	20
904	Raked	75.27	72.58	70.96	70.20	"
		10:10	12:00	1:55	3:50	
* 8W5	Undisturbed	70.37	69.94	69.96	68.42	25
* 8W5	Raked	68.09	62.43	60.81	63.10	"
		10:25	12:15	2:10	3:10	
7E8	Undisturbed	73.27	68.95	70.97	69.71	26
7E8	Raked	71.87	72.35	65.53	66.26	"
		10:45	12:30	2:30	3:25	
6W	Undisturbed	78.88	79.14	78.39	78.55	26
6W	Raked	78.33	77.36	74.84	74.85	"
		10:55	12:40	2:35	3:40	
6E	Undisturbed	74.88	75.24	74.26	74.66	25
6E	Raked	74.93	71.96	70.00	67.36	"

* Contaminated with sand.

TABLE 17. RATE OF DRYING AT LOCATION 904 COMPARING 3 SURFACES EACH UNDER AND OUTSIDE SOLARIUM TO 1/2" DEPTH (WATER TABLE AT 27 1/2") - AUGUST 11, 1967

Treatment	% Moisture (Wet Weight)			
	9:45-10:10	12:00-12:25	2:00-2:25	3:45-4:15
Undisturbed (Outside)	73.57	73.15	73.49	73.55
Undisturbed (Inside)	72.76	72.74	73.41	72.38
Roto Tilled (Outside)	73.88	70.44	64.23	65.55
Roto Tilled (Inside)	74.83	71.66	68.80	66.03
Raked (Outside)	72.96	69.58	66.14	65.46
Raked (Inside)	72.60	70.95	69.24	66.44

TABLE 18. RATE OF DRYING AT 8C5 WITH 3 SURFACES EACH UNDER AND OUTSIDE OF SOLARIUM

August 16, 1967; Water Table 40"; Air Temperature 85°.

	9:00	11:00	1:00	2:55
Untreated (Out)	62.81	62.32	59.96	59.65
" (In)	59.69	62.79	61.51	62.70
Roto Tilled (Out)	67.35	64.19	59.75	60.43
" (In)	67.57	66.82	61.11	60.19
Raked (Out)	60.78	59.04	50.17	51.92
" (In)	61.81	59.39	54.31	54.81

TABLE 19. RATE OF DRYING COMPARING 2 SURFACES EACH UNDER AND OUTSIDE SOLARIUM TO 1/2" DEPTH

August 14, 1967, at 904: Water Table 30½"; Air Temperature 80°.

	9:10	11:10	1:15	3:15
Untreated (Out)	73.65	73.38	72.93	73.39
" (In)	-	72.35	72.63	72.22
Raked (Out)	71.73	69.25	63.77	63.95
" (In)	-	69.82	67.72	65.62

August 15, 1967, at 8C5: Water Table 40"; Air Temperature 95°.

	9:05	11:00	1:00	3:00
Untreated (Out)	62.33	60.20	59.42	56.91
" (In)	62.33	63.53	60.12	58.10
Raked (Out)	64.55	61.58	55.68	52.90
" (In)	62.72	59.83	56.22	51.49

August 16, 1967, at 8C5: Water Table 40"; Air Temperature 85°.

	9:00	11:00	1:00	2:55
Untreated (Out)	62.81	62.32	59.96	59.65
" (In)	59.69	62.77	61.51	62.70
Raked (Out)	60.78	59.04	50.17	51.92
" (In)	61.81	59.39	54.31	54.81

August 22, 1967, at 8C5: Water Table 40½"; Air Temperature 75°.

	9:30	11:00	12:55	3:30
Untreated (Out)	61.92	60.80	60.47	59.38
" (In)	-	63.51	61.22	62.23
Raked (Out)	60.03	54.55	52.95	39.32
" (In)	-	55.59	56.42	46.44

TABLE 20. RATE OF DRYING ON 3 SELECTED SITES COMPARING 2 DIFFERENT SURFACES TO 1/2" DEPTH

August 22, 1967 Air Temperature 75°

		% Moisture (Wet Weight)				Water Table
Location	Treatment	9:10	11:05	1:00	3:00	
8E5	Undisturbed	59.79	46.19	47.04	52.61	37½"
8E5	Raked	59.60	55.02	45.70	47.04	"
8C5	Undisturbed	61.92	60.80	60.47	59.38	40½
8C5	Raked	60.03	54.55	52.95	39.32	"
8W5	Undisturbed	38.19	39.47	47.50	42.97	34
8W5	Raked	51.66	48.62	43.96	45.88	"

TABLE 21. RATE OF DRYING ON FIELD 7W COMPARING 3 DIFFERENT SURFACES EACH IN AND OUT OF THE SOLARIUM ON TWO CONSECUTIVE DAYS IN 1967

Treatment	% Moisture (Wet Weight)			
	August 31, 1967			
	9:00	11:00	1:00	3:00
None (Out)	61.57	66.44	56.24	57.01
" (In)		59.58	54.09	50.36
Raked (Out)	57.78	58.04	54.95	49.95
" (In)		57.33	56.88	55.54
Tilled (Out)	67.70	67.28	61.03	58.80
" (In)		66.28	62.89	64.46
	September 1, 1967			
None (Out)	60.19	54.19	55.18	50.12
" (In)	60.19	58.18	52.03	48.78
Raked (Out)	59.03	52.52	31.70	50.21
" (In)	59.03	46.28	49.85	41.88
Tilled (Out)	65.43	63.68	58.94	51.70
" (In)	65.43	62.85	57.35	55.76

TABLE 22. RATE OF DRYING ON FIELD 8C COMPARING 3 DIFFERENT SURFACES ON 3 CONSECUTIVE DAYS IN 1967 AT 3 DIFFERENT SITES

Location	Treatment	% Moisture (Wet Weight)			
		9:00	11:00	1:00	3:00
		---------September 5, 1967---------			
8E	None	57.58	57.62	62.23	53.10
8E	Tilled	62.74	60.20	56.23	59.25
8E	Raked	57.25	55.44	53.96	46.11
8C	None	51.89	57.58	45.61	53.96
8C	Tilled	63.82	63.82	58.43	53.18
8C	Raked	59.46	52.47	50.79	48.49
8W	None	49.06	46.96*	51.82	44.69*
8W	Tilled	57.74	59.07	53.35	45.47
8W	Raked	45.29	44.62	43.58	42.61
		---------September 6, 1967---------			
8E	None	53.37	55.42	51.00	48.43
8E	Tilled	67.64	61.79	59.36	54.85
8E	Raked	58.89	56.78	49.08	37.56
8C	None	48.27	44.63	49.94	47.18
8C	Tilled	61.44	55.91	56.49	50.15
8C	Raked	55.54*	45.71	45.56	43.05
8W	None	45.07	48.33	31.40*	32.70*
8W	Tilled	50.18	51.75	45.26	50.76
8W	Raked	37.69	45.77*	32.47	34.16*
		---------September 7, 1967---------			
8E	None	52.93	51.48	46.42	47.05
8E	Tilled	55.55	57.60	47.99	44.96
8E	Raked	42.73	42.03	41.56	35.04
8C	None	45.25	47.37	34.04	40.44
8C	Tilled	60.73	58.56	56.06	43.58
8C	Raked	44.81	49.29	39.60	25.16
8W	None	35.38	31.68	33.68	40.88
8W	Tilled	56.17	46.79	44.39	46.75
8W	Raked	40.86	32.01	36.86	28.50

* Sand

TABLE 23. RATE OF DRYING ON FIELD 8C COMPARING 3 DIFFERENT SURFACES EACH IN AND OUT OF SOLARIUM ON THREE CONSECUTIVE DAYS IN 1967

Treatment	% Moisture (Wet Weight)			
	9:00	11:00	1:00	3:00
	----------September 5, 1967--------			
None (Out)	51.89	57.88	45.61	53.96
" (In)	46.40	54.76	48.28	49.84
Tilled (Out)	63.82	63.82	58.43	53.18
" (In)	62.61	62.12	58.43	57.47
Raked (Out)	59.46	52.47	50.79	48.49
" (In)	50.98	51.40	41.49	43.66
	----------September 6, 1967--------			
None (Out)	48.27	44.63	49.94	47.18
" (In)	46.84	39.61	32.40	28.18
Tilled (Out)	61.44	55.91	56.49	50.15
" (In)	66.50	59.22	47.88	47.54
Raked (Out)	55.54	45.71	45.56	43.05
" (In)	52.95	51.82	50.99	32.55
	----------September 7, 1967--------			
None (Out)	45.25	47.37	34.04	40.44
" (In)	43.26	44.15	40.34	38.38
Tilled (Out)	60.73	58.56	56.06	43.58
" (In)	60.73	56.86	52.18	47.51
Raked (Out)	54.81	49.29	39.60	25.16
" (In)	53.84	-	30.60	27.23

e. On August 31, 1967, a small plot was hoed in comparison with the other treatments. A hand garden hoe was used to simply slice the surface 1/2" layer from the underlying bed and leaving the surface relatively smooth but covered with the "slabs" and "cookies" of the hoed peat. The aim was simply to break the capillary union between the surface and the main peat body. No attempt was made to fluff the peat, in fact, care was taken to leave the surface in as large as possible pieces - making sure they were no thicker than 1/2 inch. The data follows:

WATER PERCENTAGE (On Wet Weight Basis)

	9:00 (Start)	11:00	1:00	3:00
Untreated	61.37	66.44	56.24	57.01
Roto-tilled	67.70	67.28	61.03	58.80
Raked	57.78	58.04	54.29	49.95
Hoed	60.79	59.36	59.60	45.28

The experiment was repeated on September 1 with similar results.

From this limited data it would appear that harvest equipment should be designed to cut a thin layer from the field surface and to leave it unfluffed but perhaps broken loosely to maximize exposure to sun and wind.

Relationship between water table and rate of drying -- We have stated that the drainage system of a peat field should result in a minimum water table of 20 inches at the field center. The ease with which this is met is determined by the spacing of ditches. (Discussed in detail under the section on ditch spacing.) The following chart (taken from Tables 14 to 23) indicates how very important it is to have the water level low.

CORRELATION BETWEEN WATER TABLE & RATE OF SURFACE DRYING
(1967) (Reed-Sedge Peat)
(Samples taken from the top 1/2 inch of raked surfaces at various dates and from several fields)

WATER TABLE (inches)	CHANGE IN WATER PERCENTAGE (moist wt. base)	CHANGE IN WATER PERCENTAGE (max.-min. percentage)
17½	76.6-73.7	2.9
17½	74.7-74.4	.3
19	77.1-74.6	2.5
20	75.1-70.9	4.2
22½	73.1-67.0	6.1
24½	72.9-64.5	8.4
25	74.9-67.4	7.5
28	71.0-61.6	9.4
40	64.6-52.9	11.7
40½	60.0-39.3	20.7

With free water less than 20" from the surface, the rate of upward movement approaches the evaporation rate. As the water table drops, the rate of surface loss increases and it is with the implementation of this increase that the peat producer most be concerned. The minimal 20" water table will allow for the absorption of a 2" rain and still be firm enough to support field equipment. But it might reduce the possibility of realizing 100 days of harvest. In 1967, Field 7E (75' spacing) presented 106 days with the water table at 26" or more while field 9 (150 ft. spacing) had but 89. Interpolating to 100 and 125 foot widths would give figures of 101 and 95 days respectively. We conclude that harvest fields should not exceed 100 feet in width for conventional methods of field drying and that the field layout should include several 75 ft. fields for insurance.

6. Rainfall 1965 through 1967 - Wilderness Valley Farms

The appended records of rainfall for this peat area indicate that in most years 100 good harvest days will be available. In most years there will be at least one good week in May, June will offer usually three good weeks (1967 an exception), July will for the most part be good all the way through, August will be counted on for four good weeks (1966 was an exception), September and October will provide five weeks between them. A larger sampling of records would undoubtedly show other exceptions to the rule, but would substantiate the expectations for 100 harvest days. However, a peat business should certainly use each day as it comes along to the maximum -- if anything is true of Minnesota weather it is its day to day unpredictability. To pass up a good May, in hopes for a better June, etc., may prove disasterous. It would appear from experience that in months of less than 3 inches of rainfall the harvesting will, given sun, be exceptionally good.

TABLE 24. RAINFALL WILDERNESS VALLEY FARMS 1960 WITH PEAT HARVEST RECORD - FROM CHUN KING FIELD RECORDS

Record began May 12

May	19,20,21	1.05
	26	.65
	27,28,29	1.75
June	1	(trace)
	3	.22
	9	(trace)
	10	.33
	13	6 yds.
	14	42 yds.
	15	96 yds.
	16	½" rain
	17	96 yds.
	20	40 yds.
	21	160 yds.-.25" rain
	23	1.5"
	28	.26"
July	1	220 yds.
	2	.33"
	5	80 yds.
	6	190 yds.
	7	150 yds.
	8	220 yds.
	9	180 yds.
	10	.02"
	11	220 yds.
	12	220 yds.
	13	240 yds.
	14	240 yds.
	15	240 yds.
	16	1.05"
	19	240 yds.
	20	240 yds.
	21	240 yds.
	22	270 yds.
	23	300 yds.
	25	1.10"
	27	330 yds.
	28	360 yds.
	29	260 yds. - .5" rain
August	2,5	(Good harvest days, but did not operate)
	6	240 yds.
	8	1.10"
	15,18	(Good harv. days, but did not operate)
	19	.8"
	23	.10"
	24	.056"
	26	.48"
	27	(Drizzle)
	31	(Good harv. day, did not op.)
Sept.	1,6	(Good harv. day, did not op., includes a Sunday)
	7	.49"
	12	)Drizzle)
	14	(Drizzle)
	20,21	(Good harv. day, did not op.)
	24	(Drizzle)
	27,30	(good harv. day, did not op.)
Oct.	1,12	(10 good harv. days, did not op.)
	13	(Drizzle)
	18	(Snow flurries)
	22	(Last date of weather data)

TABLE 25. RAINFALL 1965 - 1967 WILDERNESS VALLEY FARMS

1965

7-30-65	.33"
8-5	.44
8-7	1.90
8-16	.1
8-25	.32
8-28, 29,30	1.50
9-4,5	.63
9-11,12	1.20
9-13,14	1.35
9-17	.42
9-18	.20
9-20,21	.40
9-22	.08
9-23	.02
9-27	.03
9-29,30	2.05
10-7,8	.54

(No records earlier than 7-30; No records later than 10-8)

1966

(Earliest record 5-17 & 19; rain all day. Amount unknown .)

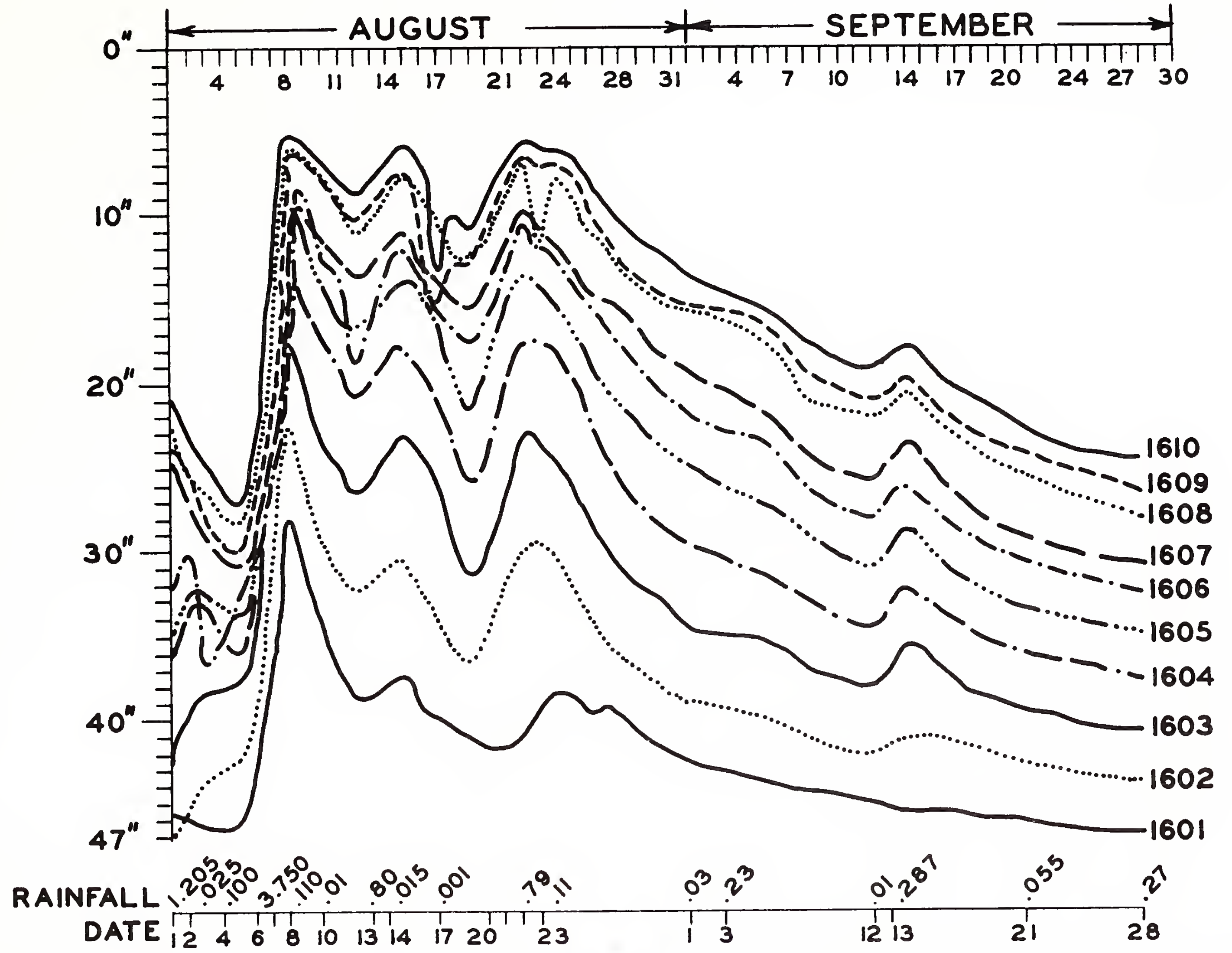
5-23-66	.220"
6-2	1.050
6-5	.540
6-12	.660
6-13,14	.015
6-16	.110
6-24	.590
6-25	.900
7-3	.590
7-4	.085
7-7	.001
7-8	.120
7-10	.045
7-17	.680
7-22	.130
7-25	.025
7-26	.220
8-1	1.205
8-2	.025
8-4	.100
8-6,7	3.750
8-8	.110
8-10	.01
8-13	.80
8-14	.015
8-17	.001
8-20, 21,22	.79
8-23	.11
9-1	.03
9-3	.23
9-12	.01
9-13	.287
9-21	.055
9-28	.27
10-2,3	.83
10-4	.217
10-14,15	.810
10-22	.100

1967

5-9-67	.15"
5-10	.36
5-12	.05
5-20	.02
5-22	.18
5-26	.05
6-4	.035
6-6	.62
6-8	.20
6-12	.20
6-13	.70
6-14	1.4
6-15	.42
6-16	.01
6-19	.44
6-20	.04
6-22	.052
6-24	.065
6-27	.96
6-28	.12
6-29	.16
7-2	.07
7-8	.09
7-10	.04
7-16	.64
7-22,23	2.27
7-24	.015
7-25	.50
7-26	.01
7-29	.05
8-1	.62
8-2	.07
8-3	.15
8-6	.36
8-7	.13
8-8	.01
8-14	.08
8-20	.07
8-25	.85
9-10	.08
9-12	.035
9-13	.76
9-14	.035
9-20	.15
9-21	.05
9-26	.03
10-3	.04
10-7,8	.025
10-13	.01
10-29	1" snow

Figure 42

WATER LEVELS AT CENTERLINE WELLS FIELD 16
REFLECTING DISTANCES BETWEEN CONVERGING DITCHES, SUMMER 1966



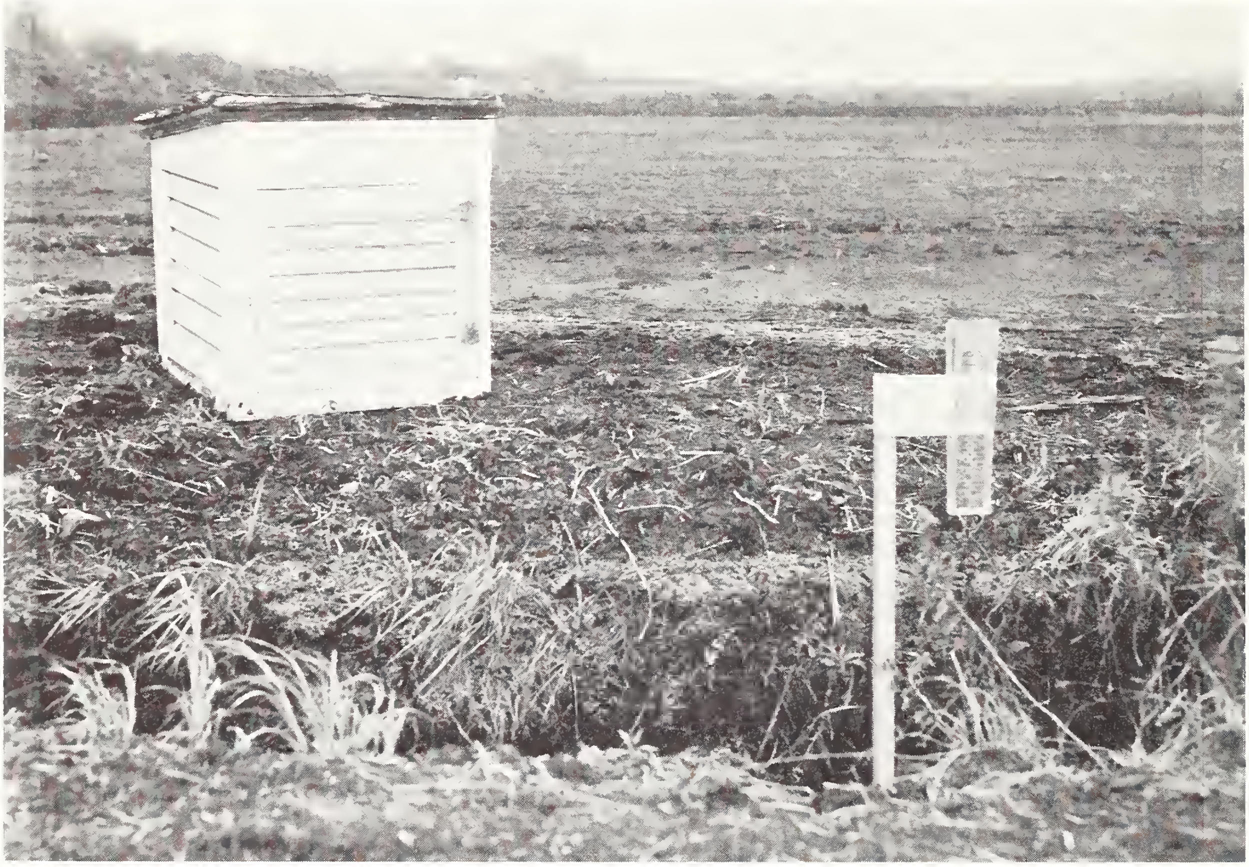


Fig. 43. Rainfall records were accumulated from measurements obtained in the rainfall gauge pictured above. The weather box housed a recording thermometer which was used to chart the season's temperature in 1967.

TABLE 26. AVERAGE WATER CONTENTS (IN ONE FOOT) OF PEAT PROFILES WITH VARYING WATER-TABLE LEVELS - 1967

Sample Depth In Inches	Range In Water-Table Level				
0"	6-12"	12-18"	18-24"	24-30"	30-36"
6	9.5	9.1	8.4	7.6	6.8
12	10.7	9.5	8.8	8.2	7.6
18	11.0 *	10.8 *	9.2	8.7	8.5
24	11.0 *	11.0 *	10.7 *	10.0	9.0
30	-	11.0 *	11.0 *	10.7 *	9.8
36	-	-	-	11.0 *	11.0 *
42	-	-	-	-	11.0 *

* Saturated with water

Examination of the field harvest records of the Chun King Corporation for 1960 (Table 24) will show that when fields are well drained, heavy rains can be absorbed rapidly and harvest proceeds with little loss of time. For example, on July 16, 1960, 1.05 inches of rain fell, yet, according to their agronomist, three days later a normal harvest was made, in the 40% moisture range. On July 25, a 1.10 inch rain fell and harvesting resumed two days later. Records of the field manager for that year indicate that 1/4-inch rains did not impede harvest at all.

There were several weeks in May and early June when harvest could have been carried on that year had the equipment been ready.

Figure 42 is offered as interesting evidence of the rapidity with which rain is taken into the body of the peat. Note the almost immediate response to heavy rain and note the lack of response to the .230 inch rain and the very noticeable one to the .287 inch rain -- recalling the earlier quotation that it takes more than a quarter inch of rain to stop peat harvest.

CONCLUSION: Good field drainage is needed to make possible the adsorption of heavy rains, insuring a minimum number of days of shutdown until harvesting can resume. The field foreman will have to harvest religiously on every day the field conditions will allow in order to get 100 harvest days in this locality.

See Table 1, page 55, for rainfall data at the Pine Island Research Area and Table 25 for Wilderness Valley Farms. Figure 43 shows instruments used in recording weather data.

7. Water contents of peats with varying water-table levels - 1967

During 1965 and 1966 considerable data was obtained of water contents of peats at different depths and with varying water-table levels. The data in Tables 27 through 38 represent new and more complete information from a number of different fields, ditch spacings, and water-table levels.

The data in Table 26 is taken from Tables 27 through 38 and averaged according to a range of water-table levels varying from 6 inches below the surface to 33 inches below.

This data shows a positive correlation of water content in upper layers with height of water table, i.e., water contents of peat are highest in upper layers where the water-table level is high. For example, with a water-table level between 6 to 12 inches from the surface the water content

TABLE 27. WATER PROFILES EXPRESSED IN PERCENT OF WET WEIGHT OF SAMPLE - 1967

Sample No.	Depth	Percent H_2O	Water Table	Date
(Location: A1602: Midway between ditches 25 ft. apart.)				7-11-67
318	6"	82.23	32½"	
319	12"	85.67	32½"	
320	24"	86.44	32½"	
321	30"	85.32	32½"	
322	36"	87.33	32½"	
323	42"	89.38	32½"	
324	48	86.52	32½"	
(Location: A1603: Midway between ditches 37½ ft. apart.)				7-11-67
325	6"	82.42	27½"	
326	12"	81.44	27½"	
327	18"	87.28	27½"	
328	24"	87.43	27½"	
329	30"	86.99	27½"	
330	36"	88.89	27½"	
(Location: A1604: Midway between ditches 50 ft. apart.)				7-11-67
331	6"	81.71	26"	
332	12"	84.98	26"	
333	18"	86.51	26"	
334	24"	84.89	26"	
335	30"	86.80	26"	
(Location: A1605: Midway between ditches 75 ft. apart.)				7-11-67
336	6"	81.16	21"	
337	12"	84.46	21"	
338	18"	86.66	21"	
339	24"	87.37	21"	
340	30"	87.96	21"	

TABLE 28. WATER PROFILES EXPRESSED IN PERCENT OF WET WEIGHT OF SAMPLE - 1967

Sample No.	Depth	Percent H_2O	Water Table	Date
(Location: 1606: Midway between ditches 100 ft. apart)				
341	6"	83.91	15½"	7-12
342	12"	83.90	15½"	7-12
343	18"	86.73	15½"	7-12
344	24"	87.89	15½"	7-12
(Location: 1606B: 30 ft. from the North one of the above ditches.)				
345	6"	83.90	19"	7-12
346	12"	84.28	19"	7-12
347	18"	85.48	19"	7-12
348	24"	86.87	19"	7-12
(Location: 1606A: 10 ft. from above ditch.)				
349	6"	81.57	28½"	7-12
350	12"	81.47	28½"	7-12
351	18"	84.30	28½"	7-12
352	24"	86.79	28½"	7-12
353	30"	86.80	28½"	7-12
354	36	86.33	28½"	7-12

TABLE 29. WATER PROFILES EXPRESSED IN PERCENT OF WET WEIGHT OF SAMPLE - 1967

Sample No.	Depth	Percent H_2O	Water Table	Date
(Location: A1606: Midway between ditches 100 ft. apart.)				
355	6"	84.35	18½"	7-12
356	12"	85.28	18½"	7-12
357	18"	86.71	18½"	7-12
358	24"	89.83	18½"	7-12
(Location: A1606B: 30 ft. from south one of the above ditches.)				
359	6"	83.77	19½"	7-12
360	12"	84.32	19½"	7-12
361	18"	86.73	19½"	7-12
362	24"	86.75	19½"	7-12
363	30"	88.70	19½"	7-12
(Location: A1606A: 10 ft. from above ditch.)				
364	6"	82.74	24"	7-12
365	12"	82.42	24"	7-12
366	18"	83.20	24"	7-12
367	24"	85.52	24"	7-12
368	30"	87.60	24"	7-12
369	36"	87.27	24"	7-12

TABLE 30. WATER PROFILES EXPRESSED IN PERCENT OF WET WEIGHT OF SAMPLE - 1967

Sample No.	Depth	Percent H_2O	Water Table	Date
(Location: 1602: Midway between ditches 16' apart.)				
300	6"	82.17	33"	7-11
301	12"	80.57	33"	7-11
302	18"	85.40	33"	7-11
303	24"	84.91	33"	7-11
304	30"	86.20	33"	7-11
305	36"	87.96	33"	7-11
306	42"	87.40	33"	7-11
(Location: 1603: Midway between ditches 40 ft. apart.)				
307	6"	83.80	28"	7-11
308	12"	83.58	28"	7-11
309	18"	86.87	28"	7-11
310	24"	86.40	28"	7-11
311	30"	86.87	28"	7-11
312	36"	87.48	28"	7-11
(Location: 1604: Midway between ditches spaced 50 ft. apart.)				
313	6"	82.56	23"	7-11
314	12"	81.38	23"	7-11
315	18"	85.65	23"	7-11
316	24"	86.70	23"	7-11
317	30"	88.04	23"	7-11

TABLE 31. WATER PROFILES EXPRESSED IN PERCENT OF WET WEIGHT OF SAMPLE - 1967

Sample No.	Depth	Percent H_2O	Water Table	Date
(* Location: 1604)				
313	6"	82.56	23"	7-11
314	12"	81.38	23"	7-11
315	18"	85.65	23"	7-11
316	24"	86.70	23"	7-11
317	30"	88.04	23"	7-11
462	6"	81.99	20½"	7-17
463	12"	82.10	20½"	7-17
464	18"	85.64	20½"	7-17
465	24"	88.59	20½"	7-17
466	30"	87.38	20½"	7-17
490	6"	82.68	22½"	7-18
491	12"	82.62	22½"	7-18
492	18"	84.33	22½"	7-18
493	24"	86.90	22½"	7-18
494	30"	87.17	22½"	7-18
985	6"	82.39	18"	7-31
986	12"	82.92	18"	7-31
987	18"	86.14	18"	7-31
988	24"	85.62	18"	7-31

* Well located midway between ditches 50 feet apart.

TABLE 32. WATER PROFILES EXPRESSED IN PERCENT OF WET WEIGHT OF SAMPLE - 1967

* Location: B1604

Sample No.	Depth	Percent H_2O	Water Table	Date
245	0-6"	81.95	28½"	7-11
246	6-12"	80.71	28½"	7-11
247	12-18"	83.39	28½"	7-11
248	18-24"	87.38	28½"	7-11
249	24-30"	87.11	28½"	7-11
250	30-36"	87.37	28½"	7-11
456	6"	82.80	26½"	7-17
457	12"	83.07	26½"	7-17
458	18"	85.59	26½"	7-17
459	24"	86.70	26½"	7-17
460	30"	87.08	26½"	7-17
461	36"	86.99	26½"	7-17
994	6"	82.33	27"	7-31
995	12"	83.01	27"	7-31
996	18"	85.60	27"	7-31
997	24"	86.76	27"	7-31
998	30"	86.17	27"	7-31
999	36"	86.60	27"	7-31

* This well located midway between ditches spaced 50 ft. apart.

TABLE 33. WATER PROFILES EXPRESSED IN PERCENT OF WET WEIGHT OF SAMPLE - 1967

Sample No.	Depth	Percent H_2O	Water Table	Date
(Location: B1606: Midway between ditches spaced 100 ft. apart.)				
257	6"	76.61	19"	7-11
258	12"	84.39	19"	7-11
259	18"	81.56	19"	7-11
260	24"	82.96	19"	7-11
(Location: B1605: Midway between ditches spaced 75 ft. apart.)				
251	6"	83.73	22½"	7-11
252	12"	82.60	22½"	7-11
253	18"	85.55	22½"	7-11
254	24"	88.03	22½"	7-11
255	30"	83.97	22½"	7-11
256	36"	85.21	22½"	7-11
(Location: B1604: Midway between ditches spaced 50 ft. apart.)				
245	6"	81.95	28½"	7-11
246	12"	80.71	28½"	7-11
247	18"	83.39	28½"	7-11
248	24"	87.38	28½"	7-11
249	30"	87.11	28½"	7-11
250	36"	87.37	28½"	7-11

TABLE 34. WATER PROFILES EXPRESSED IN PERCENT OF WET WEIGHT OF SAMPLE - 1967

Sample No.	Depth	Percent H_2O	Water Table	Date
(Location: 1608)				
273	6"	80.09	10½"	7-12
274	12"	84.36	10½"	7-12
275	18"	86.69	10½"	7-12
276	24"	87.66	10½"	7-12
(Location: A1608)				
277	6"	83.80	14"	7-12
278	12"	82.57	14"	7-12
279	18"	86.87	14"	7-12
280	24"	88.47	14"	7-12
(Location: B1608)				
281	6"	83.92	18½"	7-12
282	12"	83.44	18½"	7-12
283	18"	88.27	18½"	7-12
284	24"	88.85	18½"	7-12
285	30"	85.91	18½"	7-12

TABLE 35. WATER PROFILES EXPRESSED IN PERCENT OF WET WEIGHT OF SAMPLE - 1967

Sample No.	Depth	Percent H_2O	Water Table	Date
(Location: B1609: Midpoint between ditches 175 ft. apart.)				
519	6"	84.97	17½"	7-19
520	12"	83.34	17½"	7-19
521	18"	84.66	17½"	7-19
522	24"	86.49	17½"	7-19
602	6"	83.75	21"	7-21
603	12"	83.38	21"	7-21
604	18"	84.94	21"	7-21
605	24"	87.21	21"	7-21
606	30"	88.28	21"	7-21
1101	6"	81.95	11"	8-4
1102	12"	83.43	11"	8-4
1103	18"	88.49	11"	8-4
1115	6"	83.91	10½"	8-7
1116	12"	84.48	10½"	8-7
1117	18"	84.74	10½"	8-7

TABLE 36. WATER PROFILES EXPRESSED IN PERCENT OF WET WEIGHT OF SAMPLE - 1967

Sample No.	Depth	Percent H_2O	Water Table	Date
(Location: A1610: Midway between ditches 200 ft. apart.)				
370	6"	85.15	13½"	7-13
371	12"	82.95	13½"	7-13
372	18"	87.51	13½"	7-13
373	24"	88.80	13½"	7-13
(Location: A1610C: 60 ft. from south one of above ditches.)				
374	6"	82.86	14½"	7-13
375	12"	82.76	14½"	7-13
376	18"	88.01	14½"	7-13
377	24"	87.58	14½"	7-13
(Location: A1610A: 20 ft. from above ditch.)				
378	6"	82.59	19½"	7-13
379	12"	84.86	19½"	7-13
380	18"	85.23	19½"	7-13
381	24"	87.29	19½"	7-13
382	30"	87.69	19½"	7-13
(Location: 1610: Midway between ditches 200 ft. apart.)				
383	6"	85.48	11½"	7-13
384	12"	83.52	11½"	7-13
385	18"	86.53	11½"	7-13
(Location: 1610C: 60 ft. from the south one of the above ditches.)				
386	6"	85.28	13"	7-13
387	12"	84.02	13"	7-13
388	18"	88.07	13"	7-13
389	24"	88.59	13"	7-13
(Location: 1610A: 20 ft. from above ditch.)				
390	6"	84.67	19"	7-13
391	12"	84.95	19"	7-13
392	18"	86.67	19"	7-13
393	24"	87.50	19"	7-13

TABLE 37. WATER PROFILES EXPRESSED IN PERCENT OF WET WEIGHT OF SAMPLE - 1967

Sample No.	Depth	Percent H_2O	Water Table	Date
(Location: 1610: Midway between ditches 200 ft. apart.)				
383	6"	83.52	11½"	7-13
384	12"	86.53	11½"	7-13
385	18"	85.28	11½"	7-13
507	6"	84.90	12"	7-19
508	12"	84.74	12"	7-19
509	18"	88.49	12"	7-19
586	6"	83.58	14½"	7-21
587	12"	86.99	14½"	7-21
588	18"	87.31	14½"	7-21
589	24"	87.57	14½"	7-21
1091	6"	85.84	6"	8-4
1092	12"	85.54	6"	8-4
1107	6"	85.59	6"	8-7
1108	12"	85.80	6"	8-7

TABLE 38. WATER PROFILES EXPRESSED IN PERCENT OF WET WEIGHT OF SAMPLE - 1967

Sample No.	Depth	Percent H_2O	Water Table	Date
(Location: A1610: Midway between ditches 200 ft. apart.)				
370	6"	85.15	13½"	7-13
371	12"	82.95	13½"	7-13
372	18"	87.51	13½"	7-13
373	24"	88.80	13½"	7-13
516	6"	83.88	14"	7-19
517	12"	81.46	14"	7-19
518	18"	85.99	14"	7-19
598	6"	83.24	16½"	7-21
599	12"	80.31	16½"	7-21
600	18"	87.50	16½"	7-21
601	24"	87.92	16½"	7-21
1099	6"	84.92	8½"	8-4
1100	12"	82.35	8½"	8-4
1113	6"	83.26	8½"	8-7
1114	12"	82.76	8½"	8-7

of the peat at 6" is 9.5 inches per foot of peat. Since the peat at this density (about 10 lbs./cu. ft.) can hold 10.8 inches when saturated it has a storage capacity of only 1.3 inches per foot.

On the other hand with a water table at 30 to 36 inches below the surface the peat at 6 inches has a water content of 6.8 inches/foot or a storage capacity of 4 inches per foot of peat.

Data such as this is extremely important to a peat operator and is equally of importance to hydrologists concerned with water storage in watersheds to prevent floods. For these reasons the complete data for the several fields and varying water levels are included in this report in Tables 27 through 38.

The data in Table 26 compiled from the other 12 tables is very useful to a peat operator in determining the optimum water-table level desired.

Water Contents of Sphagnum Moss Peat (Pine Island) with Varying Depths and Water Levels - 1967

Data obtained on water contents of peats with varying water levels in the reed-sedge peat at Wilderness Valley Farms previously described may be compared with that obtained with the Sphagnum moss peat at the Pine Island research area.

Tables 39 and 40 show a range in water contents with depth and variability in amounts of water according to the ditch spacings. The data shows that Sphagnum moss peats do not retain as much water above a given water table as do the reed-sedge peats at the Wilderness Valley Farms.

Drainage, therefore, of these peats is easier than the reed-sedge peats and ditch spacings may be spaced farther apart for optimum peat harvesting. Even the 150 foot spacing which has a storage capacity for water of over 11 inches in 36 inches at a water level of 27 1/2 inches is sufficiently drained for a peat harvesting operation.

The peat in the 0 to 6 inch (surface) layers at spacings of 50 to 150 feet were all sufficiently free of water for good harvesting of surface peat. The 150 foot spacings in the reed-sedge peats at Wilderness Valley Farms, on the other hand, were not sufficiently drained for a peat operation. Spacings of 75 to 100 feet are needed for adequate drainage of these peats.

Also, the storage capacities of water which is a measure for

TABLE 39. WATER CONTENT ON VOLUME BASIS (PERCENT) IN SPHAGNUM PEAT PROFILES - PINE ISLAND - SEPTEMBER, 1967
Volume Weight = 4 lb./cu. ft. (.064 g/cc)

	Ditch Spacing			
	50'	75'	125'	150'
0-1"	25.1	16.1	28.0	21.5
1-2	35.0	25.2	26.5	25.4
2-4	33.0	30.1	28.3	33.0
4-6	32.8	50.9	39.0	38.5
6-8	26.2	57.2	45.2	50.0
8-10	35.1	50.3	64.2	52.0
10-12	45.3	64.0	64.7	65.0
12-18	50.9	70.5	76.0	70.5
18-24	55.7	76.0	85.0	72.0
24-30	76.5	78.2	91.0	71.8
30-36	76.4	88.5	90.7	82.9
Water Table	30"	29"	26 1/2	27 1/2

TABLE 40. WATER CONTENT AND STORAGE CAPACITY (INCHES) IN UPPER 36 INCHES OF SPHAGNUM PEAT - PINE ISLAND - SEPT., 1967
VOLUME WEIGHT = 4 lb./cu. ft. (.064 g/cc)

	Ditch Spacing			
	50'	75'	125'	150'
0-1"	.251	.161	.281	.215
1-2	.350	.252	.265	.254
2-4	.660	.602	.566	.660
4-6	.656	1.018	.780	.770
6-8	.524	1.144	.904	1.000
8-10	.702	1.006	1.284	1.040
10-12	.906	1.280	1.294	1.300
12-18	3.054	4.230	4.560	4.230
18-24	3.342	4.560	5.100	4.320
24-30	4.590	4.692	5.460	4.308
30-36	4.584	5.310	5.442	4.974
Total in 36" =	19.62	24.245	25.936	23.071
Total if Sat. =	34.45	34.450	34.450	34.450
Total Storage =	14.83	10.205	8.514	11.379
Water Table	30"	29"	26 1/2"	27 1/2

the peat's ability to hold water following heavy rains is much less with reed-sedge peat than with Sphagnum peat. It would take from 8 to 14 inches of rain to saturate the entire Sphagnum peat profile. This data complements the water-level data which shows that on Sphagnum moss peats rainfall has little effect on water content above the water table as long as ditch spacings are close enough to maintain the water-table levels below about 25 inches from the surface of the bog.

While the capacity to hold water is much greater for Sphagnum than it is for reed-sedge peat, from a practical standpoint, it is not advised that Sphagnum fields be ditched with spacings in excess of 125 feet. It is also recommended that ditches be constructed at least 4 feet deep to insure a 24-inch draw-down layer free of water at the mid-point of fields.

8. Water contents of peats related to bulk density

During the course of these peat investigations, 1965-1967, considerable data has been obtained under varied climatic conditions with water levels in the bogs ranging at times from near the surface to three or four feet below the surface. Water contents of peats can be expressed in several ways such as percent on a dry basis, percent on a wet basis, pounds of water per cubic foot and volumetrically as inches of water per inch or per foot of peat.

Since commercial producers of peat generally express water contents on the wet weight basis, it is useful to compare water contents with varying densities of peats on the volume and actual weight basis. Tables 41 through 58 are tables showing these water content relationships for all types of peat varying in density from 3 pounds per cubic foot to 20 pounds per cubic foot.

These tables may be used as follows:

First, to determine the density of peat it is necessary to saturate with water and determine the water content on wet basis. For example, the saturated water content of a peat sample is found to be 84.7 percent on wet basis. Refer to Table 48 and see that the density is 10 pounds per cubic foot for this peat.

Second, after determining density or type of peat using the saturation method, the water contents and storage capacity may be determined at any time or at any water-table level and using the several columns in each table, other water storage capacities can be found. If for example, again using Table 48

TABLE 41. WATER STORAGE IN PEATS AT VARIOUS WATER PERCENTAGES
BULK DENSITY 3.0 lb./cu. ft. (.048 g/cc)

Percent Water		Weight of Water Lb./cu.ft.	Inches of Water	
(Wet Basis)	(Dry Basis)		Per Inch of Soil	Per Foot of Soil
*95.3	2015	60.5	.967	11.61
95.0	1915	57.5	.919	11.03
94.8	1815	54.5	.871	10.45
94.5	1715	51.5	.823	9.88
94.1	1615	48.5	.775	9.30
93.8	1515	45.5	.727	8.73
93.4	1415	42.5	.679	8.15
92.9	1315	39.5	.631	7.57
92.4	1215	36.5	.583	7.00
91.8	1115	33.5	.535	6.42
91.0	1015	30.5	.487	5.85
90.2	915	27.5	.439	5.27
89.1	815	24.5	.391	4.69
87.8	715	21.5	.343	4.12
86.0	615	18.5	.295	3.54
83.8	515	15.5	.247	2.97
80.6	415	12.5	.199	2.39
76.0	315	9.5	.151	1.81
68.4	215	6.5	.103	1.24
53.8	115	3.5	.055	.62

* Saturated

TABLE 42. WATER STORAGE IN PEATS AT VARIOUS WATER PERCENTAGES
BULK DENSITY 4 lb/cu. ft. (.064 g/cc)

Percent Water		Weight of Water	Inches of Water	
(Wet Basis)	(Dry Basis)	Lb./cu.ft.	Per Inch of Soil	Per Foot of Soil
*93.7	1495	59.8	.957	11.48
93.3	1395	55.8	.893	10.71
92.8	1295	51.8	.829	9.96
92.3	1195	47.8	.765	9.18
91.6	1095	43.8	.701	8.41
90.0	995	39.8	.637	7.64
89.9	895	35.8	.573	6.87
88.8	795	31.8	.509	6.11
87.4	695	27.8	.445	5.34
85.6	595	23.8	.381	4.57
83.1	495	19.8	.317	3.80
79.8	395	15.8	.253	3.03
74.7	295	11.8	.189	2.27
66.1	195	7.8	.125	1.50
48.7	95	3.8	.061	.73

* Saturated

TABLE 43. WATER STORAGE IN PEATS AT VARIOUS WATER PERCENTAGES
BULK DENSITY 5 lb./cu. ft. (.080 g/cc)

Percent Water		Weight of Water	Inches of Water	
(Wet Basis)	(Dry Basis)	Lb./cu.ft.	Per Inch of Soil	Per Foot of Soil
*92.2	1183	59.1	.946	11.36
91.5	1083	54.2	.866	10.40
90.5	983	49.2	.786	9.44
89.8	883	44.2	.706	8.48
88.7	783	39.2	.626	7.52
87.2	683	34.2	.546	6.56
85.4	583	29.2	.466	5.60
82.8	483	24.2	.386	4.64
79.3	383	19.2	.306	3.68
73.9	283	14.2	.226	2.72
64.7	183	9.2	.146	1.76
45.4	83	4.2	.066	.80

*Saturated

TABLE 44. WATER STORAGE IN PEATS AT VARIOUS WATER PERCENTAGES
BULK DENSITY 6 lb./cu. ft. (.096 g/cc)

Percent Water		Weight of Water	Inches of Water	
(Wet Basis)	(Dry Basis)	Lb./cu.ft.	Per Inch of Soil	Per Foot of Soil
*90.7	975	58.5	.936	11.23
90.2	925	55.5	.888	10.66
89.7	875	52.5	.840	10.08
89.2	825	49.5	.792	9.50
88.6	775	46.5	.744	8.93
87.9	725	43.5	.696	8.35
87.1	675	40.5	.648	7.78
86.2	625	37.5	.600	7.20
85.2	575	34.5	.552	6.62
84.0	525	31.5	.504	6.05
82.6	475	28.5	.456	5.47
81.0	425	25.5	.408	4.90
78.9	375	22.5	.360	4.32
76.5	325	19.5	.312	3.74
73.3	275	16.5	.264	3.17
69.2	225	13.5	.216	2.59
63.6	175	10.5	.168	2.02
55.6	125	7.5	.120	1.44
42.9	75	4.5	.072	.86

* Saturated

TABLE 45. WATER STORAGE IN PEATS AT VARIOUS WATER PERCENTAGES
BULK DENSITY 7 lb./cu. ft. (.112 g/cc)

Percent Water		Weight of Water	Inches of Water	
(Wet Basis)	(Dry Basis)	Lb./cu.ft.	Per Inch of Soil	Per Foot of Soil
*89.2	824	57.7	.923	11.07
88.6	774	54.2	.867	10.40
87.9	724	50.7	.811	9.97
87.1	674	47.2	.755	9.06
86.2	624	43.7	.699	8.39
85.2	574	40.2	.643	7.71
84.0	524	36.7	.587	7.04
82.6	474	33.2	.531	6.37
80.9	424	29.7	.475	5.70
78.9	374	26.2	.419	5.03
76.4	324	22.7	.363	4.35
73.3	274	19.2	.307	3.68
69.1	224	15.7	.251	3.01
61.9	174	12.2	.195	2.34
55.4	124	8.7	.139	1.67
40.5	74	5.2	.083	.99

* Saturated

TABLE 46. WATER STORAGE IN PEATS AT VARIOUS WATER PERCENTAGES
BULK DENSITY 8 lb./cu. ft. (.128 g/cc)

Percent Water		Weight of Water	Inches of Water	
(Wet Basis)	(Dry Basis)	Lb./cu.ft.	Per Inch of Soil	Per Foot of Soil
*87.7	713	57.0	.913	10.95
86.9	663	53.0	.849	10.18
86.0	613	49.0	.785	9.41
84.9	563	45.0	.721	8.65
83.7	513	41.0	.657	7.89
82.2	463	37.0	.593	7.11
80.5	413	33.0	.529	6.34
78.4	363	29.0	.465	5.58
75.8	313	25.0	.401	4.81
72.5	263	21.0	.337	4.04
68.1	213	17.0	.273	3.27
62.0	163	13.0	.209	2.50
53.1	113	9.0	.145	1.74
38.7	63	5.0	.081	.97

* Saturated

TABLE 47. WATER STORAGE IN PEATS AT VARIOUS WATER PERCENTAGES
BULK DENSITY 9 lb./cu. ft. (.144 g/cc)

Percent Water			Inches of Water	
(Wet Basis)	(Dry Basis)	Weight of Water Lb./cu.ft.	Per Inch of Soil	Per Foot of Soil
*86.2	626	56.4	.901	10.82
85.6	596	53.6	.858	10.30
85.0	566	50.9	.815	9.78
84.3	536	48.2	.772	9.26
83.5	506	45.5	.728	8.74
82.6	476	42.8	.685	8.23
81.7	446	40.1	.642	7.71
80.6	416	37.4	.599	7.19
79.4	386	34.7	.556	6.67
78.1	356	32.0	.512	6.15
76.5	326	29.3	.469	5.63
74.7	296	26.6	.426	5.11
72.7	266	23.9	.383	4.60
70.2	236	21.2	.340	4.08
67.3	206	18.5	.296	3.56
63.8	176	15.8	.253	3.04
59.3	146	13.1	.210	2.52
53.6	116	10.4	.167	2.00
46.2	86	7.7	.124	1.49
35.9	56	5.0	.081	.97

* Saturated

TABLE 48. WATER STORAGE IN PEATS AT VARIOUS WATER PERCENTAGES
BULK DENSITY 10 lb./cu. ft. (.159 g/cc)

Percent Water		Weight of Water	Inches of Water	
(Wet Basis)	(Dry Basis)	Lb./cu.ft.	Per Inch of Soil	Per Foot of Soil
*84.7	557	55.7	.886	10.63
84.1	527	52.7	.838	10.06
83.2	497	49.7	.790	9.48
82.4	467	46.7	.743	8.91
81.4	437	43.7	.695	8.34
80.3	407	40.7	.647	7.77
79.0	377	37.7	.599	7.19
77.6	347	34.7	.552	6.62
76.0	317	31.7	.504	6.05
74.2	287	28.7	.456	5.48
72.0	257	25.7	.409	4.90
70.0	227	22.7	.361	4.33
66.3	197	19.7	.313	3.76
62.5	167	16.7	.266	3.19
57.8	137	13.7	.218	2.61
51.7	107	10.7	.170	2.04
43.5	77	7.7	.122	1.35
32.0	47	4.7	.075	.90

* Saturated

TABLE 49. WATER STORAGE IN PEATS AT VARIOUS WATER PERCENTAGES
BULK DENSITY 11 lb./cu. ft. (.176 g/cc)

Percent Water		Weight of Water	Inches of Water	
(Wet Basis)	(Dry Basis)	Lb./cu.ft.	Per Inch of Soil	Per Foot of Soil
*83.3	500	55.0	.880	10.56
82.5	470	51.7	.827	9.93
81.5	440	48.4	.774	9.29
80.4	410	45.1	.722	8.66
79.2	380	41.8	.669	8.03
77.9	350	38.5	.616	7.39
76.2	320	35.2	.563	6.76
74.4	290	31.9	.510	6.12
72.2	260	28.6	.458	5.49
69.7	230	25.3	.405	4.86
66.7	200	22.0	.352	4.22
62.9	170	18.7	.299	3.59
58.3	140	15.4	.246	2.96
54.8	110	12.1	.194	2.33
46.8	80	8.8	.141	1.69
35.5	50	5.5	.088	1.06
18.0	20	2.2	.035	.42

* Saturated

TABLE 50. WATER STORAGE IN PEATS AT VARIOUS WATER PERCENTAGES
BULK DENSITY 12 lb./cu. ft. (.192 g/cc)

Percent Water		Weight of Water	Inches of Water	
(Wet Basis)	(Dry Basis)	Lb./cu.ft.	Per Inch of Soil	Per Foot of Soil
*81.8	453	54.3	.870	10.44
81.2	423	51.8	.812	9.75
79.8	393	47.2	.755	9.05
78.5	363	43.6	.697	8.36
76.9	333	40.0	.639	7.67
75.3	303	36.4	.582	6.98
73.2	273	32.8	.524	6.29
70.9	243	29.2	.467	5.60
68.1	213	25.6	.409	4.91
64.6	183	22.0	.351	4.22
62.5	153	18.4	.294	3.53
55.7	123	14.8	.236	2.83
48.2	93	11.2	.179	2.14
43.1	63	7.6	.121	1.45
28.4	33	4.0	.063	.76

* Saturated

TABLE 51. WATER STORAGE IN PEATS AT VARIOUS WATER PERCENTAGES
BULK DENSITY 13 lb./cu. ft. (.208 g/cc)

Percent Water (Wet Basis)	Percent Water (Dry Basis)	Weight of Water Lb./cu.ft.	Inches of Water Per Inch of Soil	Inches of Water Per Foot of Soil
*81.3	411	53.4	.855	10.26
79.2	381	49.5	.792	9.51
77.8	351	45.6	.730	8.76
76.2	321	41.7	.668	8.01
74.4	291	37.8	.605	7.26
72.3	261	33.9	.543	6.51
69.8	231	30.0	.480	5.77
66.8	201	26.1	.418	5.02
63.0	171	22.1	.356	4.27
58.5	141	18.3	.293	3.52
52.6	111	14.4	.231	2.77
44.7	81	10.5	.168	2.02
34.4	51	6.6	.106	1.27
17.4	21	2.7	.044	.52

* Saturated

TABLE 52. WATER STORAGE IN PEATS AT VARIOUS WATER PERCENTAGES
BULK DENSITY 14 lb/cu. ft. (.225 g/cc)

Percent Water (Wet Basis)	Percent Water (Dry Basis)	Weight of Water Lb./cu.ft.	Inches of Water Per Inch of Soil	Inches of Water Per Foot of Soil
*79.1	376	52.6	.846	10.15
77.6	346	48.4	.779	9.34
75.9	316	44.2	.711	8.53
74.1	286	40.0	.644	7.72
71.9	256	35.8	.576	6.91
69.3	226	31.6	.509	6.10
66.2	196	27.4	.441	5.29
62.4	166	23.2	.374	4.48
57.6	136	19.0	.306	3.67
51.5	106	14.8	.239	2.86
43.2	76	10.6	.171	2.05
36.2	46	7.3	.104	1.24
13.7	16	2.2	.036	.43

* Saturated

TABLE 53. WATER STORAGE IN PEATS AT VARIOUS WATER PERCENTAGES
BULK DENSITY 15 lb./cu. ft. (.241 g/cc)

Percent Water		Weight of Water Lb./cu.ft.	Inches of Water	
(Wet Basis)	(Dry Basis)		Per Inch of Soil	Per Foot of Soil
*77.6	347	52.0	.836	10.04
76.6	327	49.1	.788	9.46
75.4	307	46.1	.740	8.88
74.2	287	43.1	.692	8.30
72.8	267	40.1	.643	7.72
71.2	247	37.1	.595	7.14
69.4	227	34.1	.547	6.56
67.4	207	31.1	.499	5.99
65.2	187	28.1	.451	5.41
62.5	167	25.1	.402	4.83
59.5	147	22.1	.354	4.25
56.0	127	19.1	.306	3.67
51.8	107	16.1	.258	3.09
46.6	87	13.1	.210	2.52
41.9	67	10.1	.161	1.94
33.6	47	7.1	.113	1.36
21.5	27	4.1	.065	.78

* Saturated

TABLE 54. WATER STORAGE IN PEATS AT VARIOUS WATER PERCENTAGES
BULK DENSITY 16 lb./cu. ft. (.256 g/cc)

Percent Water (Wet Basis)	Percent Water (Dry Basis)	Weight of Water Lb./cu.ft.	Inches of Water Per Inch of Soil	Inches of Water Per Foot of Soil
*76.2	321	51.3	.822	9.86
75.1	302	48.3	.773	9.28
73.8	282	45.1	.722	8.66
72.4	262	41.9	.671	8.05
70.8	242	38.7	.620	7.43
68.9	222	35.5	.568	6.82
66.9	202	32.3	.517	6.21
64.5	182	29.1	.466	5.59
61.8	162	25.9	.415	4.98
58.7	142	22.7	.364	4.36
55.0	122	19.5	.312	3.75
50.5	102	16.3	.261	3.13
45.0	82	13.1	.210	2.52
39.4	62	9.9	.159	1.90
29.5	42	6.7	.108	1.30
17.9	22	3.5	.056	.68

* Saturated

TABLE 55. WATER STORAGE IN PEATS AT VARIOUS WATER PERCENTAGES
BULK DENSITY 17 lb./cu. ft. (.272 g/cc)

Percent Water		Weight of Water	Inches of Water	
(Wet Basis)	(Dry Basis)	Lb./cu.ft.	Per Inch of Soil	Per Foot of Soil
*74.8	298	50.6	.811	9.73
73.5	278	47.3	.756	9.07
72.1	258	43.9	.702	8.42
70.4	238	40.5	.647	7.77
68.6	218	37.1	.593	7.12
66.4	198	33.7	.539	6.46
64.0	178	30.3	.484	5.81
61.2	158	26.8	.430	5.16
58.0	138	23.5	.375	4.50
54.1	118	20.1	.321	3.85
49.5	98	16.7	.267	3.20
43.8	78	13.3	.212	2.55
36.7	58	9.9	.158	1.89
27.5	38	6.5	.103	1.24
15.3	18	3.1	.049	.59

* Saturated

TABLE 56. WATER STORAGE IN PEATS AT VARIOUS WATER PERCENTAGES
BULK DENSITY 18 lb./cu. ft. (.288 g/cc)

Percent Water		Weight of Water	Inches of Water	
(Wet Basis)	(Dry Basis)	Lb./cu.ft.	Per Inch of Soil	Per Foot of Soil
*73.5	278	50.0	.801	9.61
72.1	258	46.4	.743	8.92
70.4	238	42.8	.685	8.23
68.6	218	39.2	.628	7.53
66.4	198	35.6	.570	6.84
64.0	178	32.0	.513	6.29
61.2	158	28.4	.455	5.46
57.9	138	24.8	.397	4.78
54.1	118	21.2	.340	4.08
49.5	98	17.6	.282	3.36
43.8	78	14.0	.225	2.70
36.7	58	10.4	.167	2.00
27.5	38	6.8	.109	1.31
15.0	18	3.2	.052	.62

* Saturated

TABLE 57. WATER STORAGE IN PEATS AT VARIOUS WATER PERCENTAGES
BULK DENSITY 19 lb./cu. ft. (.304 g/cc)

Percent Water		Weight of Water	Inches of Water	
(Wet Basis)	(Dry Basis)	Lb./cu.ft.	Per Inch of Soil	Per Foot of Soil
*72.1	259	49.2	.787	9.45
70.5	239	45.4	.727	8.72
68.7	219	41.6	.666	7.99
66.6	199	37.8	.605	7.26
64.2	179	34.0	.544	6.53
61.4	159	30.2	.483	5.80
58.2	139	26.4	.423	5.08
54.3	119	22.6	.362	4.34
49.7	99	18.8	.301	3.61
44.1	79	15.0	.242	2.88
37.1	59	11.2	.179	2.15
28.1	39	7.4	.119	1.42
16.0	19	3.6	.058	.69

* Saturated

TABLE 58. WATER STORAGE IN PEATS AT VARIOUS WATER PERCENTAGES
BULK DENSITY 20 lb./cu. ft. (.320 g/cc)

Percent Water (Wet Basis)	Percent Water (Dry Basis)	Weight of Water Lb./cu.ft.	Inches of Water Per Inch of Soil	Inches of Water Per Foot of Soil
*70.7	243	48.6	.778	9.33
69.0	223	44.6	.714	8.56
67.0	203	40.6	.650	7.80
64.7	183	36.6	.586	7.03
62.0	163	32.6	.522	6.26
58.8	143	28.6	.458	5.49
55.2	123	24.6	.394	4.72
50.7	103	20.6	.330	3.96
45.4	83	16.6	.266	3.19
38.7	63	12.6	.202	2.42
30.1	43	8.6	.100	1.20
18.7	23	4.6	.074	.88

* Saturated

with a bulk density of 10 pounds per cubic foot, one determined by analysis th t a sample contains 70 percent water (wet basis), it can be seen that each cubic foot of this type (bulk density) peat contains 22.7 pounds of water and each foot of soil has 4.33 inches of water stored.

Tables 41 through 43 are for Sphagnum moss peat which has bulk densities varying from 3 to 5 pounds per cubic foot. Tables 44 through 48are for reed-sedge type peat much the same as that occurring in the bogs at Wilderness Valley Farms and varies in bulk density from 6 to 10 pounds per cubic foot. Tables 49 through 58 are for decomposed peats much like that at our basic area at Meadowlands.

These tables are very useful for peat producers to help them determine water content of their peat of a certain density at any point in time. They are useful for predicting ditch spacings necessary for a particular peat and to know how much more additional drying is necessary for a given peat on a particular harvesting day.

Using Table 41, which is an example of water storage characteristics for a Sphagnum moss peat, the percent water (wet basis) at saturation is 95.3 percent. This is 60.5 pounds of water for each cubic foot. Notice that at approximately one-half this amount of water - 30.5 pounds per cubic foot - the percent water on wet basis is 91.0 percent or only a little over 4 percent reduction on a percent basis.

Such data has lead to confusion on the part of commercial peat producers regarding percentages and actual amounts of water held by peats. This is why tables such as these are very useful to a peat producer.

At the other extreme, Table 58 shows water contents of a very dense peat (20 pounds/cu. ft.). Note that at saturation this peat has a percent of only 70.7 (wet basis) and 48.6 pounds of water, while at percents of about 50 the water content on a weight basis is still over 20 lbs./cu. ft.

9. Conventional field capacity water content experiments - 1967

A conventional field capacity water content experiment was conducted at both fields 7E and 9 during September, 1967, to determine the maximum amount of water peat will hold against the forces of gravity. This type of experiment is commonly used by soil scientists to estimate the upper limit of water a soil will hold which is available for plant growth.

In this case the objective of the experiment was to determine how wet the upper layer of peat becomes after thoroughly

TABLE 59. FIELD CAPACITY WATER CONTENTS OF PEATS SEPTEMBER, 1967

	FIELD 9 *		FIELD 7E **	
TIME (hours)	WATER CONTENT in/ft	(% wet basis)	WATER CONTENT in/ft	(% wet basis)
0	6.0	77.2	6.7	79.5
1	6.2	77.9	7.0	79.9
2	6.2	77.8	7.1	80.7
4	6.1	77.7	7.1	80.6
6	6.2	78.0	7.0	79.6
12	7.0	80.4	7.0	80.3
24	6.0	77.0	6.3	78.8
48	6.1	77.5	6.2	78.6
72	6.0	77.2	6.5	79.1

* Water Table at 40" (Field 9)

** Water Table at 30" (Field 7E)

Bulk Density of Peat = 9.0 lbs./cu.ft.

wetting the surface when the water table was at an average depth of 30 inches or lower. In other words, how wet is the surface peat after a heavy rain?

Experimental Method -- This experiment was conducted by using a rectangular metal container 30" x 30" and about 4" deep which was open at the top and bottom. This container was pushed into the upper layer of peat about 1½ inches deep and water added to a level about 2 inches above the surface level and maintained there by use of a large metal drum full of water. The surface peat was kept supersaturated for 2 to 3 days by a steady stream of water from the storage drum. The total amount of water added to the 30 inch by 30 inch peat area was 75 gallons, or the equivalent of about 19 inches of water such as rainfall.

Samples were collected at intervals starting with 0 time when the water soaked into the upper peat layer, 1 hour, 2 hours, 4 hours, 6 hours, 12 hours, 24 hours, 48 hours, and 72 hours later. A total of 9 samples were taken randomly within the peat area at a depth of 2 to 5 inches.

Samples were analyzed for water content.

Results -- Table 59 shows the data resulting from this experiment. The water contents are remarkably constant during the 72 hours following the application of 75 gallons (19 inches) of water. Because of the very low density of the peat (9.0 lbs./cu.ft.) and the large amount of unfilled pores in the surface peat, from 32 to 40% of total volume, the water moves rapidly downward, then both vertical and horizontal in the layers just below the surface towards the water table at 30 to 40 inches from the surface. This is why the peat does not become saturated at the surface. Also this is what could be expected to happen during a heavy rain. The only way the upper layers can be saturated is when the water table level is sufficiently near the surface so that the water added will saturate the unfilled pores.

The data also shows that the water contents were higher at most sampling times in Field 7E where the water table was at 30 inches than in Field 9 with the water level at 40 inches.

Data earlier in this report (Table 26) convincingly shows the relationship between water content at the surface and water table levels. The higher the water-table the higher the content of water in the peat layers at the surface and conversely the lower the water-table the lower is the content of water in the peat at the surface.

10. Water flow studies

Five piezometers were installed around well 7E2. They were of our standard well stock (1¼" aluminum pipe) crimped at the bottom end and perforated only for the bottom 14 inches. They were all set so that the perforated length cut through the 24 to 36 inch strata of the peat profile. They were arranged roughly in a circle around the well with the radius being about 30 inches. The accompanying diagram shows the relative positions and exact measurements (Figure 44).

Data was collected by sucking the water from a piezometer to a depth of 38" and then noting the time it took for the water to refill the pipe. This was done by employing the "bubbling" technique used in reading the standard wells. The graduated copper tube was lifted 3" above the level of the water in the piezometer, then by lightly blowing through the tube the water could be heard as it reached the first 3" level. The time was noted and tallied. The "bubbler" was then raised another 3" and the process repeated. This was done 6 times; the readings in the table are for each 3 inch increment and are not accumulative - each succeeding 3" rise took longer than the preceeding one. The first 3 or 4 "draw-downs" and timed readings were not used as they were very much out of line - taking considerable longer than the rest of the trials made.

The water level in 7E2 was at about 8" during the week the data was collected. Three accumulated "draw-downs" of piezometers A & E resulted in a 1/2" drop in the level of 7E2, and after a full day of testing the well dropped 2 inches. The other piezometers had no or only slight effect upon the level of the well.

Data in this report from Section 24 presents normal changes in the water level of the 4 piezometers. Readings were taken weekly and any changes are due only to rainfall, evaporation and the unassisted movement due to percolation and slope. (See Figure 45).

Table 60. contains data collected in 1967 from these areas.

Results and Conclusions -- The flow of water in a vertical and horizontal direction within the peat body is important since it is realted to the drainability of peats when ditched.

Rates of water movement within the reed-sedge peat (hydraulic conductivity) were measured in field 7E below the water table by use of the piezometers previously described. Measurements were made in piezometer tubes to obtain values for time of a 3 inch rise in water and these were used to calculate the saturated hydraulic conductivity for five sites.

Figure 44

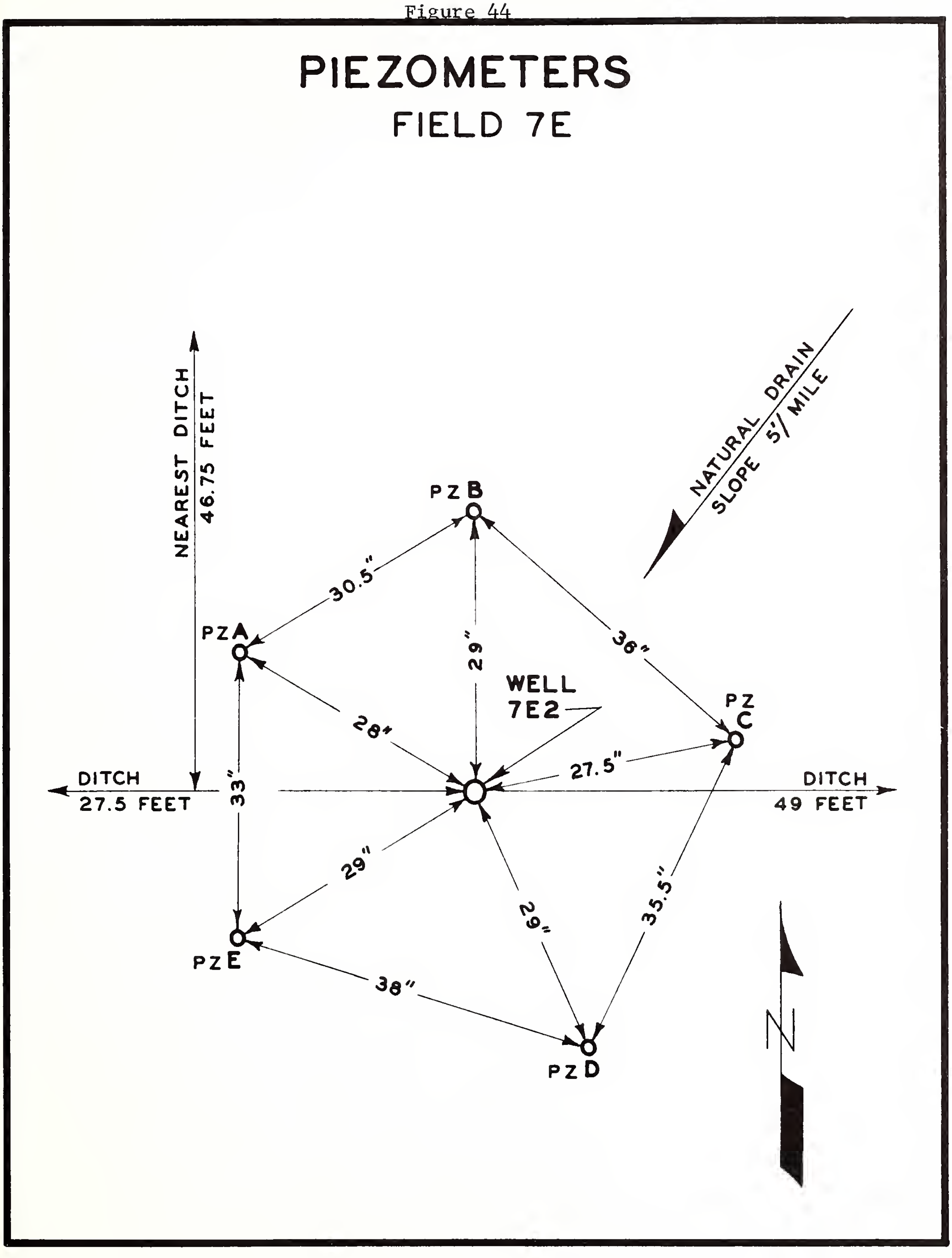
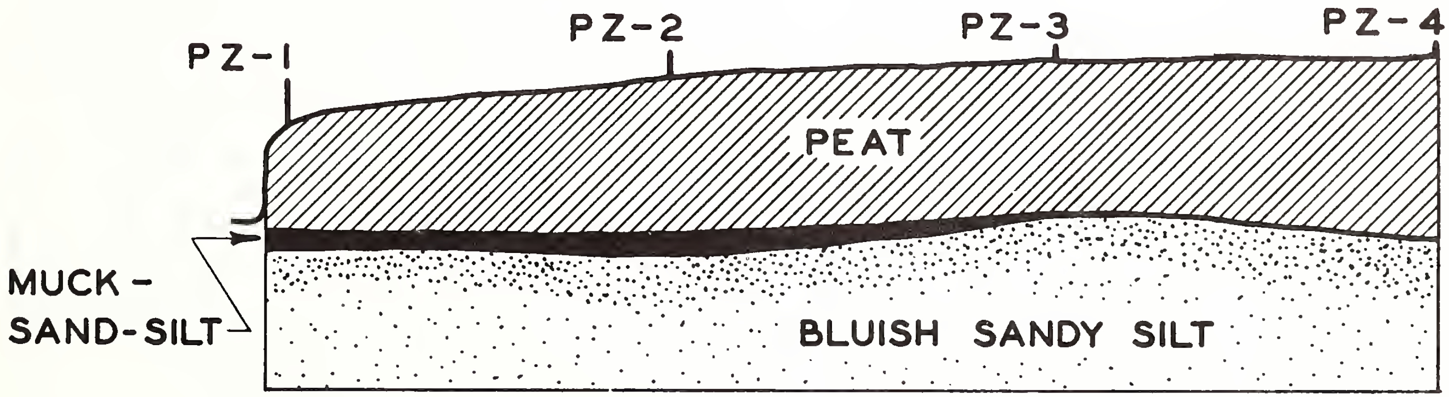

PIEZOMETERS
FIELD 7E
NEAREST DITCH
46.75 FEET
NATURAL DRAIN
SLOPE 5'/ MILE
PZ B
30.5"
29"
36"
PZ A
WELL
7E2
PZ C
28"
27.5"
DITCH
27.5 FEET
33"
DITCH
49 FEET
29"
29"
35.5"
PZ E
38"
PZ D
N

Figure 45

PIEZOMETERS SEC. 24

SCALE : VERTICAL, 1 INCH = 10 FEET - HORIZ. 1 INCH = 250 FEET



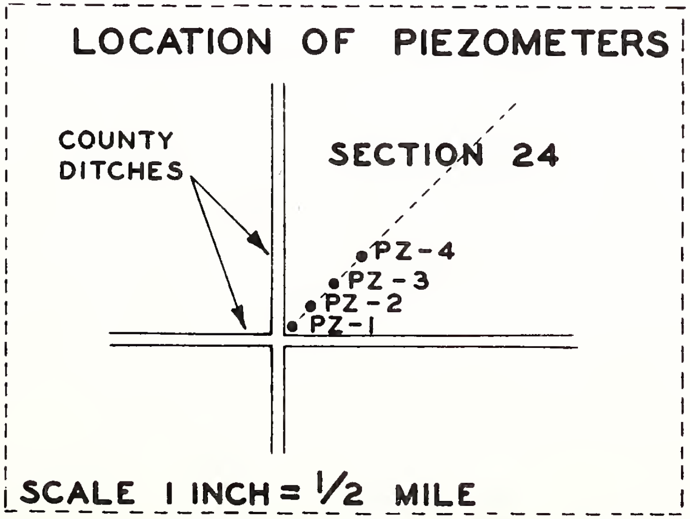


TABLE 60. PIEZOMETER READINGS: FIELD 7E SEPTEMBER 8-14, 1967; AT WELL 7E2

TIME WATER TOOK TO RISE 3" TO SUCCESSIVE HEIGHTS ABOVE DRAW-DOWN

Total Readings Made	PZ	3"	6"	9"	12"	15"	18"
23	A	21"	23"	28"	36"	51"	75"
10	B	1'56"	2'11"	2'28"	3'06"	3'44"	4'54"
12	C	26"	30"	30"	36"	46"	1'05"
8	D	37"	39"	45"	51"	1'06"	1'30"
9	E	1'0"	1'13"	1'22"	1'42"	2'13"	3'0"

THE ABOVE AVERAGES RANGED BETWEEN THE FOLLOWING EXTREMES

A	15"-27"	13"-28"	20"-35"	28"-46"	31"-62"	55"-1'43
B	1'46"-2'15"	1'55"-2'33"	2'11"-2'50"	2'35"-3'30"	3'14"-4'35"	3'53"-6'18"
C	23"-30"	20"-35"	27"-34"	30"-44"	39"-55"	56"-1'18"
D	33"-40"	35"-45"	40"-50"	45"-57"	58"-1'10"	1'19"-1'45"
E	45"-1'15"	1'05"-1'20"	1'13"-1'30"	1'30"-1'52"	2'0"-2'25"	2'37"-3'20"

PIEZOMETER A - 12.5 in/day rate
B - 3.2 in/day rate
C - 14.4 in/day rate
D - 10.4 in/day rate
E - 5.2 in/day rate

These rates for the reed-sedge peat compare favorably to those of other investigators where field techniques such as these were used. The variations from 3.2 in/day movement to 14.4 in/day are slow when compared to rates for sandy soils but are not too much different from those reported for clay soils when saturated. Apparently the horizontal fiber orientation in reed-sedge peats contributes to the low hydraulic conductivities as well as the decomposed material filling interstitial spaces between fibers.

11. Artificial drying of peat

A special drying study was conducted during the period 1 July through 31 August, 1967, to evaluate the effects of variable temperatures and moisture percentages on the rewetting potential of peat for commercial production.

All tests were conducted on peats of original undisturbed densities of .048 g/cc., .114 g/cc., and .199 g/cc., previously located and described as Arlberg Sphagnum peat, Wilderness Valley Farms reed-grass-sedge peat, and Meadowlands decomposed peat, respectively. The above volume-weight determinations were made with the following procedure:

> Peat is sampled in the profile where it exhibits the most uniformity and undisturbed blocks of about 300 cm^3 each are removed with a double-serrated knife to insure a clean cut. Samples are then placed in rigid sealed containers to prevent sample damage. In the laboratory, samples are carefully removed and placed on blotters, at which time they are saturated very slowly by hand with a wash bottle using deionized water, then saturated from below by allowing them to stand in a shallow, covered basin of water for a period of not less than 24 hours. Coincident with this last step, a beaker of paraffin is heated to liquid and held at a temperature just above that of solidification. The sample is rechecked for approximate saturation and then submerged in the liquid paraffin until sufficiently coated to be impermeable to water transfer. Sample displacement of water at 25° C. is determined as well as the total weight of the coated sample. Volume weight determinations are made of the solid paraffin by the same method and recorded, to allow for a correction of the paraffin coating, the volume of coating being

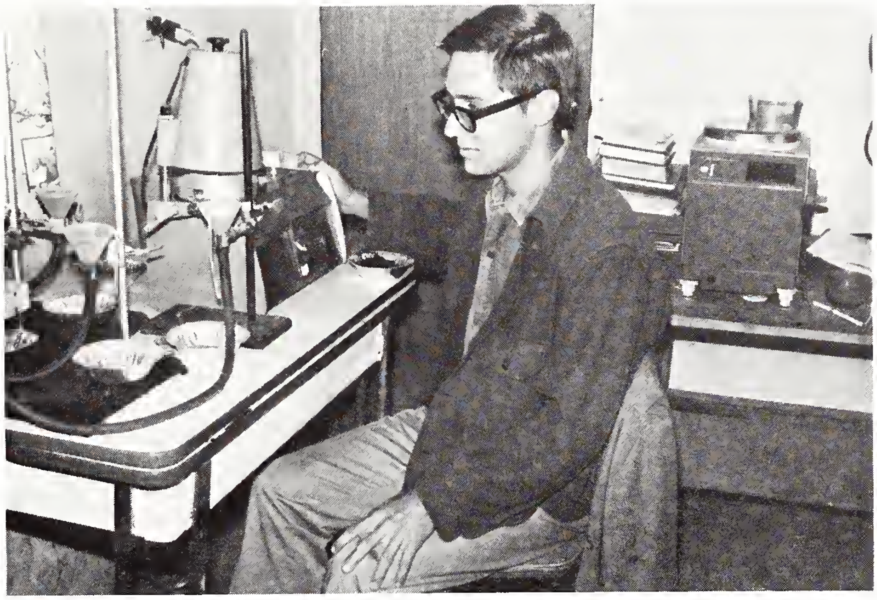


Fig. 46. Laboratory equipment used in measuring the effects of varied temperatures used in drying of peat upon its rewetability. An infra-red lamp is used for drying.

subtracted from the gross displaced volume. The sample is placed in an oven at 105° C. and dried to constant weight. As paraffin is stable at this temperature, its weight is subtracted from the gross dry weight, leaving the oven dry weight of the sample, which is converted to grams per cubic centimeter. This procedure, has proven reliable by correlations with specific measurements and is easily reproduceable. The results of this procedure, for the three basic peats studied, are mentioned above, and are those used for all subsequent moisture determinations on the volume basis. Bulk densities of peat disturbed as by shredding or stirring with agricultural implements are determined in the following manner:

Samples of undisturbed peat are collected as outlined above and shredded using a Lindig Soil Shredder, Model 5K224E32 equipped with a 2 H.P. electric motor. Six 200 cc. increments of loose peat are then placed in a 1500 cc. polyethylene graduated cylinder, with 1/8" holes bored in a solid bottom. Loss in drainage water is prevented by fitting a single Eaton-Dikeman filter paper grade 615 in the bottom of the cylinder. The graduated cylinder complete with peat is submerged in a 10,000 cc. Nalgene pipette jar containing enough water to equal the height of peat in the cylinder, the level of water being kept at this height for one hour. The cylinder is removed and water passed into the peat from above at the rate of 50 cc. per minute for 5-10 minutes. Another 200 cc. increment of peat is added and the same procedure repeated until 1000 cc. of saturated peat are contained in the graduated cylinder, at which time the gross weight is recorded and the peat placed in a 105° C. oven to constant weight. The volume weight is thus determined in grams per cubic centimeter for disturbed peat, the values for Arlberg Sphagnum Peat, Wilderness Valley Farms reed-grass-sedge peat, and Meadowlands decomposed peat being .048 gm/cc., .095 g/cc., and .141 g/cc. respectively.

The removal of water from peat by artificial means is important as most methods of commercial peat processing utilize such means in some form. One such method is a rotary dryer which utilizes the application of high temperatures. An experiment designed to measure the effects of variable temperatures for different lengths of time of soils of different densities was established using applied infra-red radiation. A 115 volt, 50-60 cycle variac O'Haus Moisture Balance, Model No. 6100 with 100 gram capacity was used for this experiment, equipped with a 250 watt infra-red bulb. The balance is manufactured by O'Haus Scale Corporation, Union, New Jersey. (See Figure 46.)

The initial procedure was a calibration check to fix points of variable temperatures, at which time the three basic peats previously cited were dried to constant weight at an applied temperature of 70° C. Actual peat temperatures varied lower or higher depending upon the amount of water remaining in the sample and reradiation values. Thus an applied temperature of 70° C. could, by reradiation result in dry peat temperatures in excess of 160° C. Rates of water loss at different points in time were noted as well as changes in temperature with moisture reduction. The result being a measure of water loss per unit time.

In addition to the preceding experiment, the change in reabsorptive potential of peats after exposure to high temperatures was measured in the following way:

Samples of the preceding densities were dried so that 10 grams of water were removed from a 100 gram saturated sample in increasing increments, a sample being removed at each interval and its reabsorptive potential tested by complete submergence in water in a confined container, permeable to water, for a period of 24 hours, at which time excess water is removed by free drainage for 6 hours in a large box, the inside of which is kept at 100% relative humidity.

Results of the calibration check are shown in Table 61 and Figures 47, 49, 51 , in tabular form in the former and plotted as the rate of moisture release as a function of temperature and time in the latter.

An examination of Figure 47 shows an initial moisture release lag through the first ten minutes, while vapor pressures increase to a point where substantial water vapor losses will occur. A peak rate of removal occurs at 88° C. and continues high to a point corresponding with 96° C. actual peat temperature. Further application of heat results in a moisture loss of but 1.5 g/°C. from 115° C. to the temperature at which oxidation occurs, 115° C.

The moisture lost from 30-60 minutes represents a steady decline of the rate of water removal. During this period, temperatures increase at an increasing rate while water losses decrease at an increasing rate. Thus as the Total Amount of water remaining in the sample becomes smaller, less applied heat is required for heat of vaporization and more can be utilized to heat the material being dried. A converse situation exists for the First 30 minutes of the

TABLE 61. REWETTING POTENTIAL AFTER VARIABLE EXPOSURES TO HIGH TEMPERATURES -- ARLBERG SPHAGNUM (95 g. water and 5 g. dry peat)

SAMPLE	GRAMS H_2O REMOVED	ACTUAL SURFACE TEMP. °C.	PERCENT H_2O AFTER REWET
1	95 (total)	155	412
2	90	135	890
3	80	115	930
4	70	96	2120
5	60	93	2160
6	50	90	2264
7	40	88	2251
8	95	70	1895
9	95	80	1828
10	95	90	1783
11	95	100	1704
12	95	110	1162

WILDERNESS VALLEY FARMS BASIC AREA (90 g. water and 10 g. dry peat)

SAMPLE	GRAMS H_2O REMOVED	ACTUAL SURFACE TEMP. °C.	PERCENT H_2O AFTER REWET
15	90 (total)	130	291
16	80	110	404
17	70	96	881
18	60	90	895
19	50	87	910
20	40	86	901
21	90	70	426
22	90	80	410
23	90	90	407
24	90	100	401
25	90	110	439
26	90	120	340
26 (a)	90	130	366

MEADOWLANDS DECOMPOSED PEAT (86 g. water and 14 g. dry peat)

SAMPLE	GRAMS H_2O REMOVED	ACTUAL SURFACE TEMP. °C.	PERCENT H_2O AFTER REWET
27	86 (total)	110	250
28	80	106	224
29	70	100	310
30	60	97	299
31	50	91	528
32	40	90	650
33	86	80	560
34	86	90	267
35	86	100	249
36	86	110	197

Figure 47

RATE OF MOISTURE RELEASE AS A FUNCTION OF TEMPERATURE AND TIME USING INFRARED RADIATION

ARLBERG SPHAGNUM PEAT

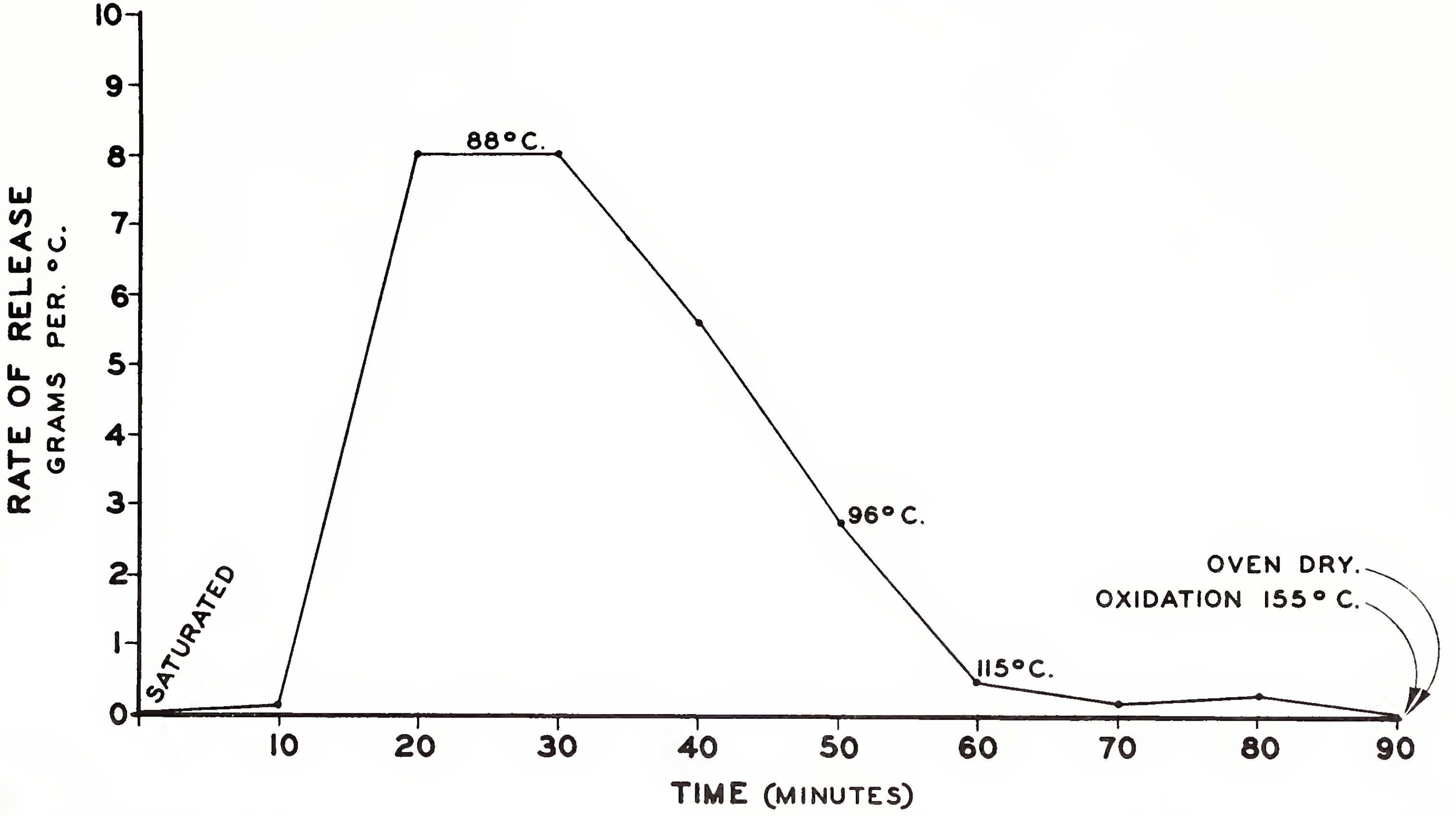
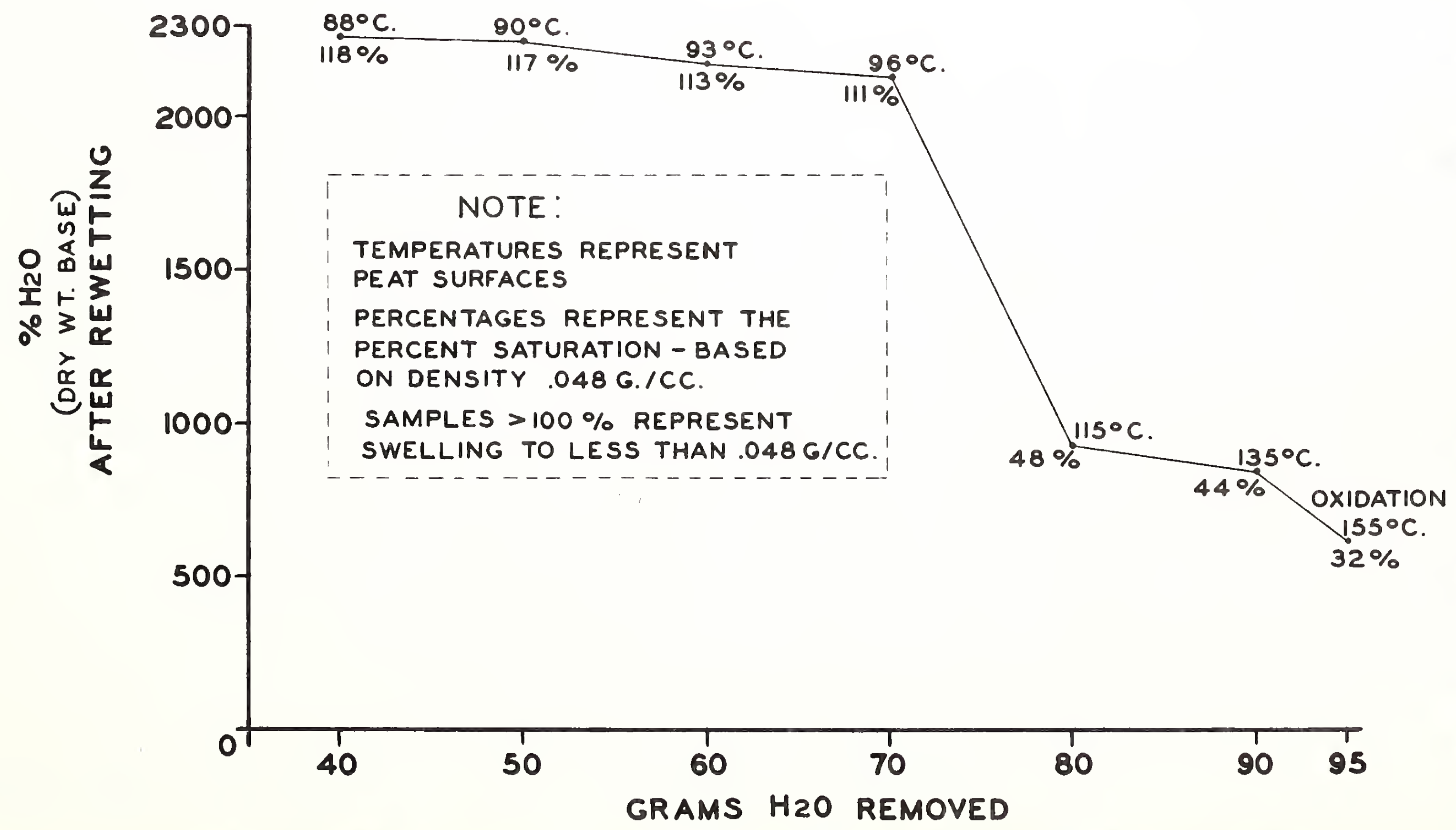


Figure 48

REWETTING POTENTIAL OF ARLBERG SPHAGNUM PEAT AFTER PARTIAL DRYING FROM SATURATION

(95 G. H_2O + 5 G. OVEN DRY PEAT)



NOTE:

TEMPERATURES REPRESENT PEAT SURFACES

PERCENTAGES REPRESENT THE PERCENT SATURATION - BASED ON DENSITY .048 G./CC.

SAMPLES >100% REPRESENT SWELLING TO LESS THAN .048 G/CC.

Figure 49

RATE OF MOISTURE RELEASE AS A FUNCTION OF TEMPERATURE AND TIME USING INFRARED RADIATION

WILDERNESS FARMS REED GRASS - SEDGE PEAT

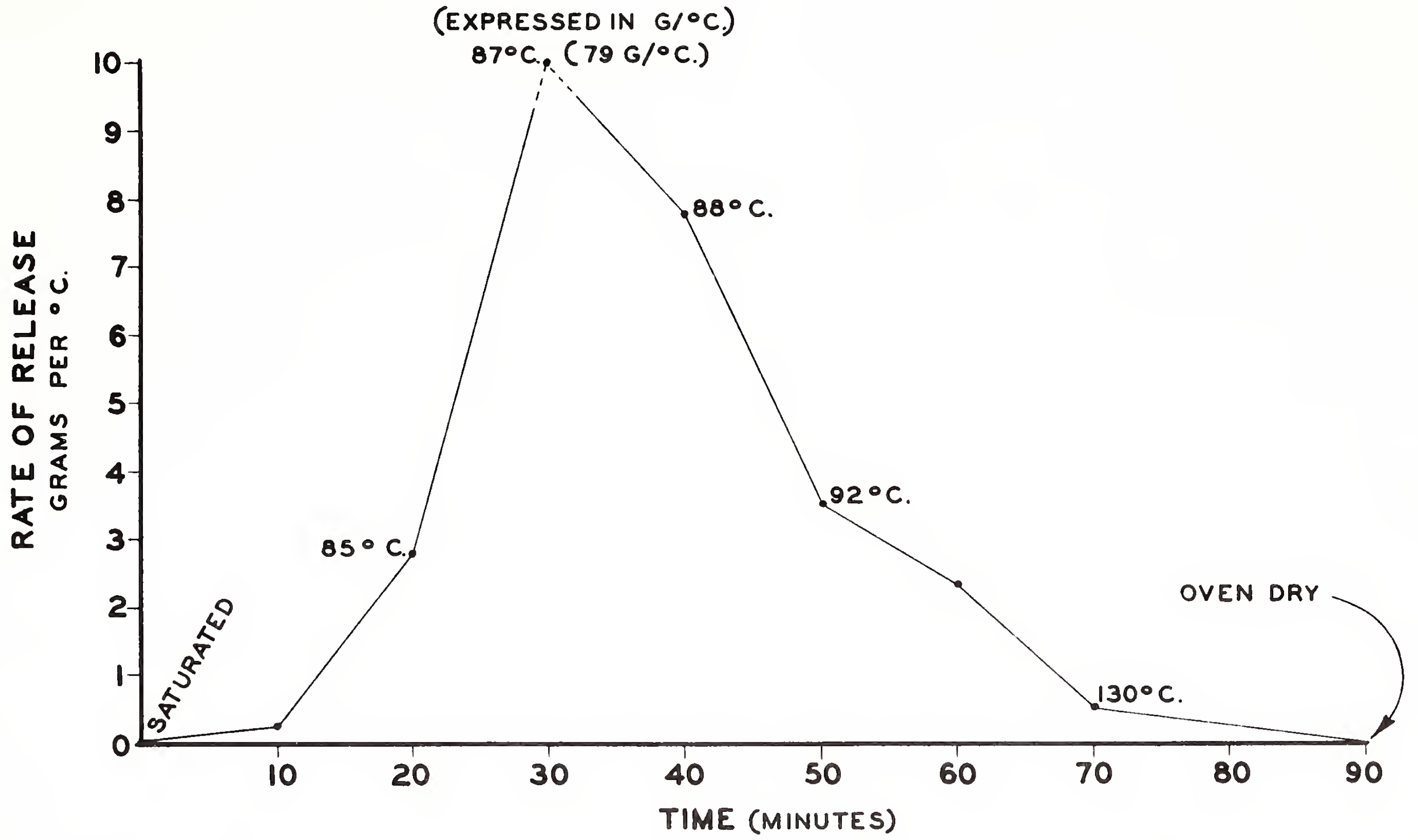
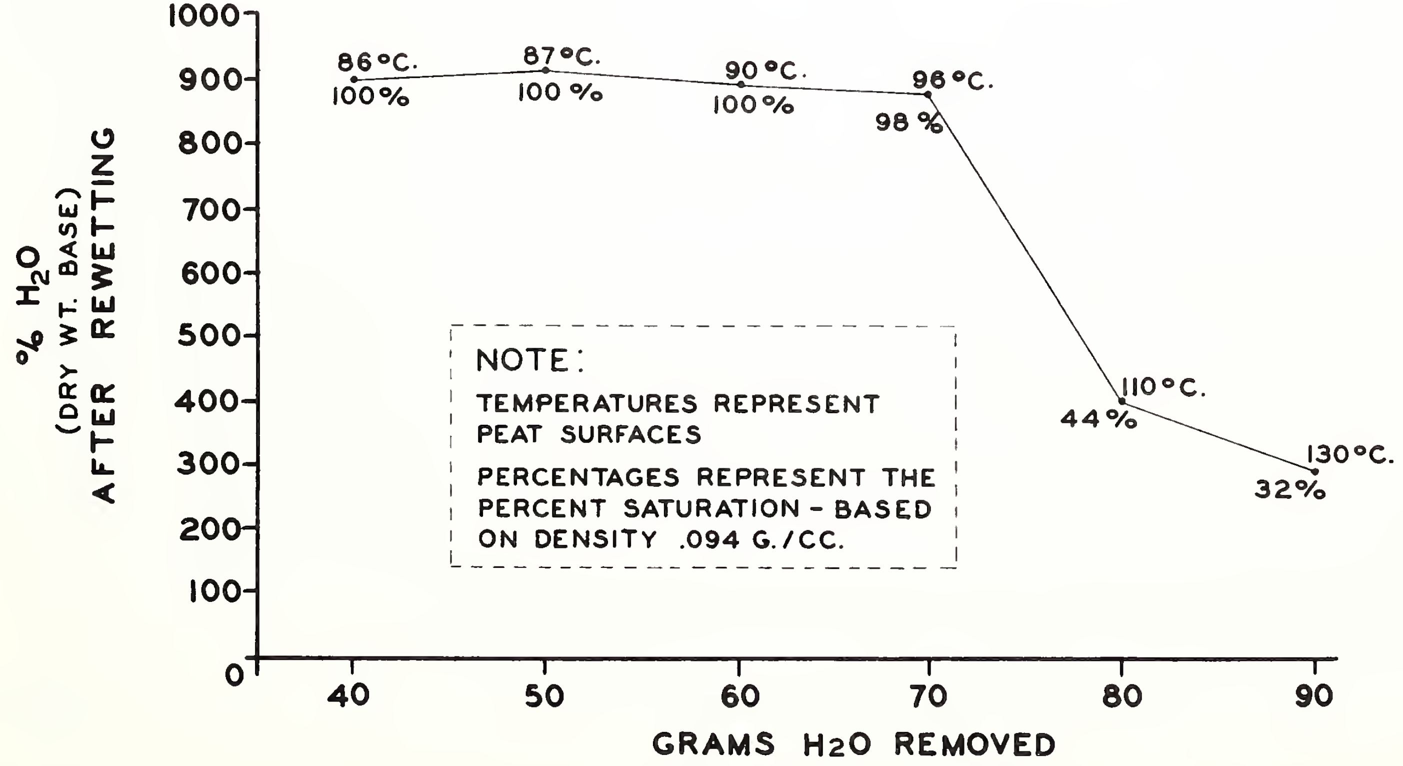


Figure 50

REWETTING POTENTIAL OF WILDERNESS FARMS
REED - SEDGE PEAT
AFTER PARTIAL DRYING FROM SATURATION
(90 G. H_2O + 10 G. OVEN DRY PEAT)



NOTE:
TEMPERATURES REPRESENT PEAT SURFACES
PERCENTAGES REPRESENT THE PERCENT SATURATION - BASED ON DENSITY .094 G./CC.

Figure 51

RATE OF MOISTURE RELEASE AS A FUNCTION OF TEMPERATURE AND TIME USING INFRARED RADIATION

MEADOWLANDS DECOMPOSED PEAT

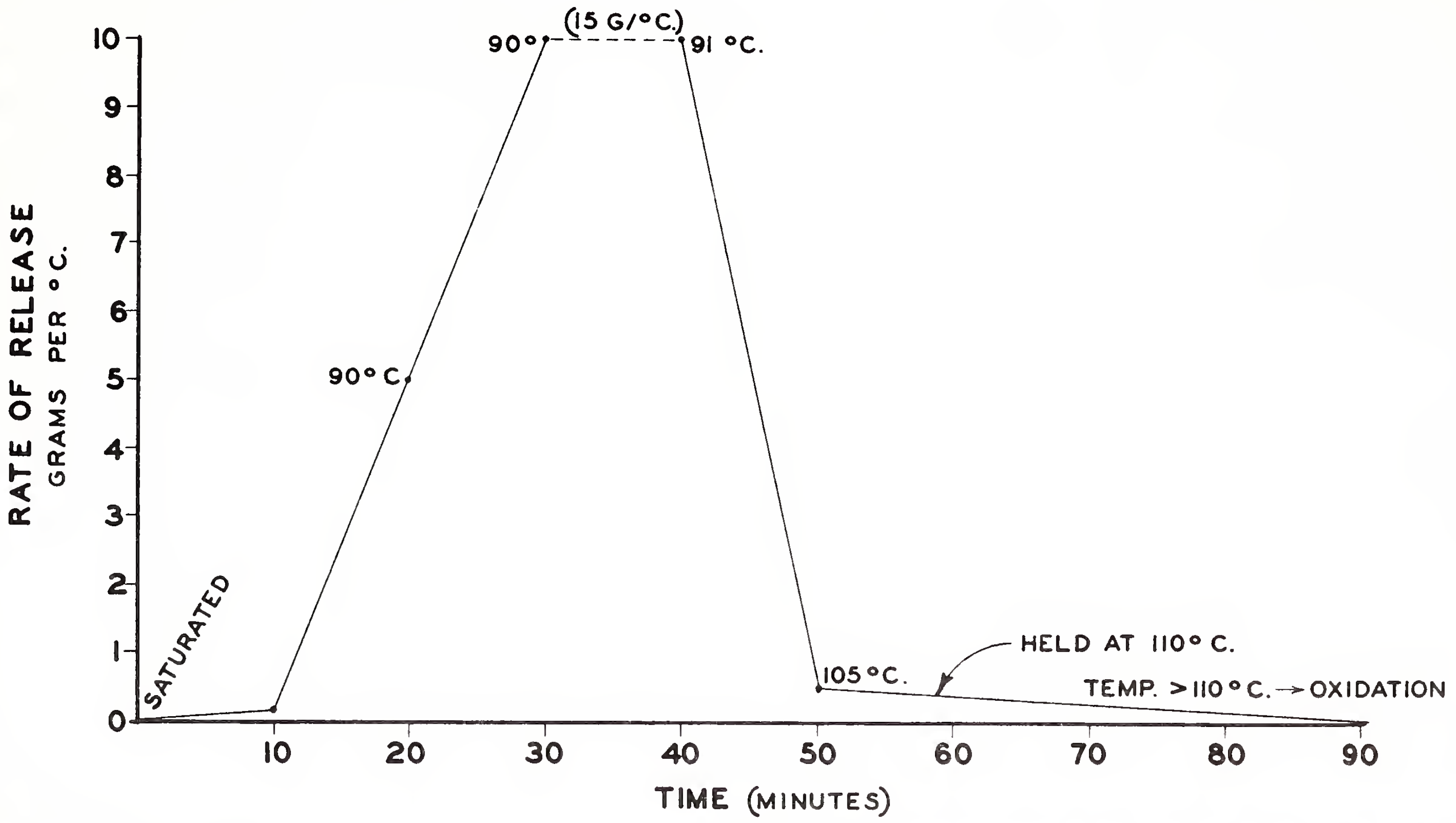
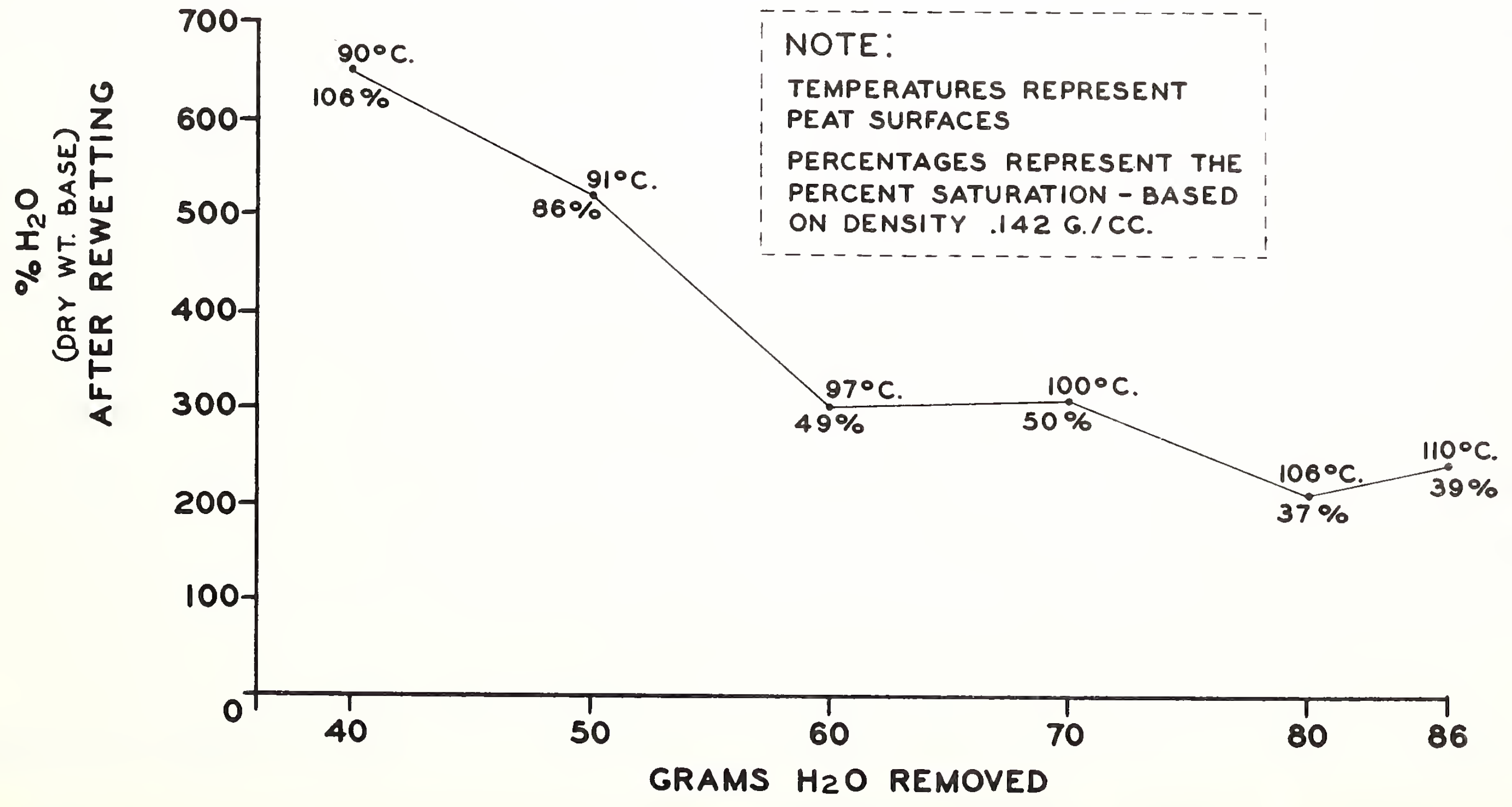


Figure 52

REWETTING POTENTIAL OF MEADOWLANDS DECOMPOSED PEAT AFTER PARTIAL DRYING FROM SATURATION

(86 G. H_2O + 14G. OVEN DRY PEAT)


NOTE:

TEMPERATURES REPRESENT PEAT SURFACES

PERCENTAGES REPRESENT THE PERCENT SATURATION - BASED ON DENSITY .142 G./CC.

drying period, or that period culminated by peak rates of water removal, where both the total amount and rate of removal of water is greater, more heat being utilized in vaporization than in heating the material under scrutiny. Thus the period of greatest moisture release rate is marked by the least changes in temperature.

Examination of Figures 49 and 51 also illustrate the same processes, but at slightly different temperatures, as different pore sizes and distributions and particle size ranges hold water more or less tenaciously during its removal.

An examination of Figures 48, 50 and 52 shows the effects of the processes previously expressed as rewetting potential, or that equilibrium moisture content attained after complete submergence in water for a 24-hour period, expressed as percent moisture on a dry weight basis. Soil temperatures are noted at all points on the curve, as is the percent saturation, or the percent of the total water which could be held at saturation by the three basic peats at the densities previously cited. Note that at points on the curve for Arlberg Sphagnum peat, moisture contents in excess of that at saturation occur, an illustration of the potential expansion of that material when saturated in a relatively unconfined container.

Both curves 48 and 50 exhibit sharp declines in rewetting potential at sample temperatures of 96° C., while that for Meadowlands decomposed peat, Figure 52 , declines quite rapidly at temperatures in excess of 90° C., indicating possible structural or cellular damage at these temperatures. All three peat types show a definite decline in rewetting potential at temperatures approaching 100° C.

Upon re-examination of Figures 48, 50 and 52 , a distinct correlation appears between rate of water removal, rewetting potential and temperature. Considering these three factors, the following table is suggested as a production guideline for peat processing to yield a product suitable for commercial markets. Note that the peats under scrutiny represent only the three broad categories of most peat produced commercially. As peats vary in ash content, particle size distribution and other physical properties, so will they vary somewhat from the suggested guidelines.

Peat Type	Suggested Temp. Range ° (C)	Percent of Total Water Removed	Percent Saturation When Rewetted	Percent Moisture of Product	
				Moist Wt. Basis	Dry Wt. Basis
Arlberg Sphag.	88-96	42-74	118-111	91-83	1100-500
Fens Reed Sedge	86-96	44-78	100- 98	83-67	550-200
Meadowlands Decomp.	90-91	46-58	106- 86	77-72	333-257

High temperature and excess moisture reduction tend to substantially reduce the rewetting potential of processed peat. The table below shows the effects of these extremes.

Peat Type	Temp. Range ° C	Percent of Water Removed	Percent Saturation When Rewetted	Percent Moisture of Product	
				Moist Wt. Basis	Dry Wt. Basis
Arlberg Sphag.	Greater than 97	75-100	48-32	80-0	440-0
Fens Reed Sedge	Greater than 97	79-100	44-32	64-0	180-0
Meadowlands Decomp.	Greater than 91	59-100	49-39	70-0	240-0

Because most dryers presently in use for commercial peat processing vary in specifications, the first table above outlines a suggested range of temperatures and expected moisture relations which should be suitable for production for each of the three broad categories of peat.

Before an equilibration of the data here presented can be made with actual production conditions, however, two qualifications must be emphasized: 1. that rewetting potential is determined after complete submergence in water for a period of 24 hours, so that the potentials given in Table 61 will tend to be high, as a similar period of time is not feasible for peat utilization by the consumer.

Therefore, procedural recommendations would tend to favor lower peat temperatures and higher product moisture percentages for best quality peat. 2. The peat used for experimental purposes was not collected as a surface mulch, but was bulk harvested and shredded. Extremely high surface temperatures often result in peat too low in moisture to properly rewet. Most peat, especially Sphagnum, is damaged when handled and processed after having been overdried either naturally or artificially, as is oftentimes the case.

12. Peat compression studies

Future commercial peat processing may involve the use of compression in the production of a product of lower moisture content and greater dry mass per unit volume. Such a procedure can be attempted in the laboratory using a small hydraulic press fitted with appropriate piston and cylinders.

For this experiment, a Walker hydraulic jack, Model 935, Series R, of capacity 16,000 pounds was used. The jack was modified with an overhead press plate which can be raised or lowered depending on the length of compression stroke. A series of 2 cylinders was manufactured in which the sample to be pressed is placed. Holes of 1/16" and 1/8" for outside and inside cylinders respectively, were bored throughout to provide adequate drainage for the peat sample during the presssing process.

Samples pressed include Arlberg Sphagnum, Wilderness Farms reed-grass sedge, and Meadowlands white-cedar peat, whose basic locations and profiles have been previously recorded. The data is shown in Table 62. Density determinations were made of the above types using several methods, the most acceptable of which to date utilizes undisturbed, paraffin-coated samples. Recorded densities by the above method are: 3.0 lb./ft. ^{3} (.048 g/cc), 7.1 lb./ft. ^{3} (.114 g/cc) and 12.1 lb./ft. ^{3} (.199 g/cc) for the above peats respectively.

The cylinder capacity is approximately one liter. Samples to be pressed were pre-shredded when field moist to obtain greater uniformity. Peat of each of the three above types was placed by hand into the cylinder and pressed. After pressing, each sample was carefully removed and measured to the nearest .1 cm, the volume calculated, and a subsample dried to constant weight at 100° C for 12-18 hours. A compression ratio, or the ratio of densities before and after pressing are then calculated. Thus a ratio of 5.00/1 with Arlberg Sphagnum indicates a final volume weight of 15 lb./ft. ^{3} (.24 g/cc.).

The two most important determinations in a study such as this are the compression ratio and the final moisture content, the former being an indicator of the mass weight of a product prepared for transport, the latter being directly related to the rewetting potential of the sample.

The compression ratio indicates how well a sample of definite density can be pressed with pressure. From a commercial production standpoint, however, a more meaningful measure of the final product is the volume weight, by which samples of

TABLE 62. PEAT COMPRESSION DATA

SAMPLE	PRESSURE (ram)	PRESSURE (psi)	SAMPLE VOL (cc) (pressed)	SAMPLE DENSITY (g/cc) (field)	SAMPLE DENSITY (g/cc) (pressed)	COMPRESSION RATIO	PERCENT H_2O (moist)	PERCENT H_2O (dry)
ARLBERG	17000		118	.048	.251	5.22/1	58.8	143.0
SPHAGNUM	17000	783.8	206	.048	.231	4.81/1	65.7	192.0
"	16000	737.7	236	.048	.157	3.27/1	6 9.1	223.0
"	16000		236	.048	.148	3.08/1	69.1	224.0
"	16000		275	.048	.166	3.46/1	69.2	224.0
"	16000		259	.048	.173	3.60/1	69.2	224.0
"	16000		283	.048	.168	3.50/1	69.0	223.0
"	12000	553.2	275	.048	.156	3.25/1	70.8	242.0
"	12000		275	.048	.156	3.25/1	70.7	241.0
"	8000	368.8	291	.048	.151	3.15/1	75.5	309.0
"	8000		314	.048	.150	3.13/1	75.6	309.0
"	4000	184.4	314	.048	.155	3.23/1	78.9	371.0
"	4000		314	.048	.153	3.18/1	78.8	371.0
W.V.F.	10000	461.0	105	.114	.358	3.14/ 1	62.0	163.0
REED-SEDGE	13000	599.3	275	.114	.334	2.93/1	59.0	144.0
"	11000	507.1	2 51	.114	.305	2.67/1	64.1	179.0
"	11000		243	.114	.284	2.49/1	66.4	197.0
"	11000		283	.114	.304	2.67/1	65.3	187.4
"	11000		306	.114	.309	2.71/1	65.4	188.6
"	11000		283	.114	.297	2.60/1	65.3	187.5
"	10000	461.0	314	.114	.283	2.48/1	67.9	212.0
"	10000		322	.114	.295	2.59/1	67.9	212.0
"	8000	368.8	306	.114	.272	2.39/1	71.2	248.0
"	8000		330	.114	.266	2.33/1	71.2	248.0
"	6000	276.6	385	.114	.251	2.20/1	74.4	291.0
"	6000		369	.114	.225	1.97/1	74.4	291.0
"	4000	184.4	353	.114	.228	2.00/1	75.0	300.0
"	4000		385	.114	.239	2.10/1	75.0	300.0
MEADOWLANDS	6000		291	.199	.263	1.32/1	73.8	282.0
DECOMPOSED	6000		(not det)	.199	(not det)	(not det)	74.5	292.0
"	6000	276.6	291	.199	.271	1.36/1	74.1	287.0
"	6000		314	.199	.266	1.34/1	74.1	287.0
"	6000		322	.199	.259	1.30/1	74.1	287.0
"	6000		236	.199	.273	1.37/1	74.1	287.0
"	5000	230.5	306	.199	.268	1.35/1	74.0	285.0
"	5000		283	.199	.273	1.37/1	74.0	285.0
"	4000	184.4	393	.199	.261	1.31/1	74.8	297.0
"	4000		322	.199	.270	1.36/1	74.8	297.0
"	3000		385	.199	.260	1.31/1	75.0	300.0
"	3000	138.3	416	.199	.258	1.30/1	75.0	300.0

different original density can be compared. With Sphagnum, over all ranges of pressure, the final volume did not vary considerably, (.150 g/cc - .173 g/cc) for 184 and 738 p.s.i., respectively. Final moisture percentages varied considerably with different amounts of pressure, the former increasing with decreasing pressure, although the final volume weight did not change appreciably over the range of pressure. This may possibly be explained by the fact that as increased pressure is applied at high pressures, water is squeezed out on the compression stroke, but the resistance of the solids to further compression inhibits further packing of the fibers. Interpreted another way, there seems to be a near maximum pressure for each type of peat, where further compression is inhibited, although more water will continue to be removed.

Although the ranges of moisture content vary with pressure, they are all within the range of product workability and rewetting. Thus a pressure of 184 p.s.i. versus 738 p.s.i. with Sphagnum may yield nearly equivalent results in terms of final volume weight attained, these being .154 g/cc and .162 g/cc, respectively. The same relationship holds true for each of the other two basic sample types. The significant difference between pressing Sphagnum versus a more highly decomposed type is the extreme resistance to compression of the latter, with sample loss through the water outlets occurring as pressures exceed a certain point. These points of maximum pressure were determined as 599 p.s.i. for the reed-grass sedge and 277 p.s.i. for the Meadowlands white-cedar types.

Although high pressures cannot be reached when pressing peat of medium to high decomposition, the resulting volume weight of these two types remains consistently higher than that for Sphagnum.

In the final analysis the lower pressures coupled with higher initial volume weight yields a final product of greater density than that reached with less dense material at considerably higher pressures.

A comparison of optimum pressures for three types of peat of different density coupled with final pressed volume weight shows that the difficulty of pressing decomposed peat is offset by its high initial density.

Conversely, pressed Sphagnum peat requires more pressure to achieve a well-pressed product, but achieving these pressures is a relatively easy task.

As mentioned previously, all samples tested were of adequate final moisture content to properly rewet when refluffed as with a shredder.

The effects of compression on peat quality, expressed as rewetting potential, or the percent moisture on the dry weight basis after submergence in water for a period of 24 hours, are illustrated below:

Peat Type	Ram Pressure (psi) (on 1 17/32" ram)	Pressure (psi) (actual)	Rewetting Potential ($\%\ H_2O$ dry wt.)	Percent Saturation
Meadowlands				
Dec.	6000	276.6	671%	109%
" "	5000	230.5	590%	96%
" "	4000	184.4	606%	99%
" "	3000	138.3	594%	97%
Wilderness Valley Farms Reed Sedge				
" " "	11000	507.1	763%	85%
" " "	10000	461.0	773%	86%
" " "	8000	368.8	733%	81%
" " "	6000	276.6	830%	92%
" " "	4000	184.4	939%	104%
Arlberg Sphagnum				
" "	16000	737.7	2048%	107%
" "	12000	553.2	2129	112%
" "	8000	368.8	2421	127%
" "	4000	184.4	2421	127%

As mentioned previously in the discussion of the effects of temperature on rewetting potential, the percent saturation may exceed 100% in cases where unconfined samples expand to a lower density than that determined by the gravitimetric method of density determination, also discussed in that report. (Refer to page 165). The potentials either approach or exceed 100% in all cases except when ram pressures greater than 6000 psi are applied to W.V.F. reed grass-sedge peat. The optimum pressures previously recommended, however, do not exceed 6000 psi for this peat type.

The samples tested above were shredded before their potentials to reabsorb moisture were checked, as would be the recommended procedure for commerical production utilizing pressure for water removal.

There is no question of the superior quality of a peat after processing by compression when compared to the final product passing through an artificial dryer. Compressing peat does not affect the ability of the peat to rewet.

13. Induced peat drying experiment

An experiment was designed to induce the drying of peat in a field by decreasing the depth of peat strata and isolating them from the capillary rise of the underlying water table. (See Figure 53.)

The object of the experiment was to determine the maximum drying of peat of varying thicknesses using plants to extract water and to compare this with a bare peat area under field conditions where evaporation alone caused the loss of water.

This type of experiment has practical significance to a peat operation as it represents the absolute maximum dryness that could be expected in the surface few inches of peat under field conditions.

On 8 August, 1967, a series of four plots was established, designed to measure the rate of moisture loss over time under cropped and bare conditions. Field 7-E, Wilderness Valley Research Farms, was chosen for the site. An area 12' x 6', consisting of two strips 12' x 3', subdivided into sections 3' x 3' in each strip was laid out and excavated to 3", 6", 9" and 12" depths. On this base, a sheet of polyethylene was laid, which overlapped all four sides of the entire plot, all 8 sections were subdivided into exclusive units by divider boards. Excavated peat was replaced to its original site of removal, the peat for each plot having previously been collected and kept separate. Moisture determinations were made at this time and recorded. One-half of the area (4 plots of 3, 6, 9 and 12 inch depths) was seeded to Caribou rye. Young seedlings were visible on 12 August. On 26 August, the strip planted to rye was considered a complete cropped surface (no peat visible when viewed from above.)

On 1 September, the plots were covered continuously with a polyethylene frame at approximately four feet above the surface. On 10 September the 3" isolated plot wilted. It had not recovered turgor by 8:00 A.M. 11 September, although the relative humidity during the previous night exceeded 90%. The entire 3" plot, both cropped and bare, was harvested on 11 September and tested in quadruplicate for moisture content. Part of the cropped plot was saved for density determinations by the paraffin-coating method previously mentioned in the experiment on the effects of hydraulic compresssion of peat. On 19 September, the 6" isolated plot exhibited symptoms of wilting, and was subsequently excavated with adjacent bare peat, and the same determinations of moisture made. Part of this cropped plot was also saved for density determinations.

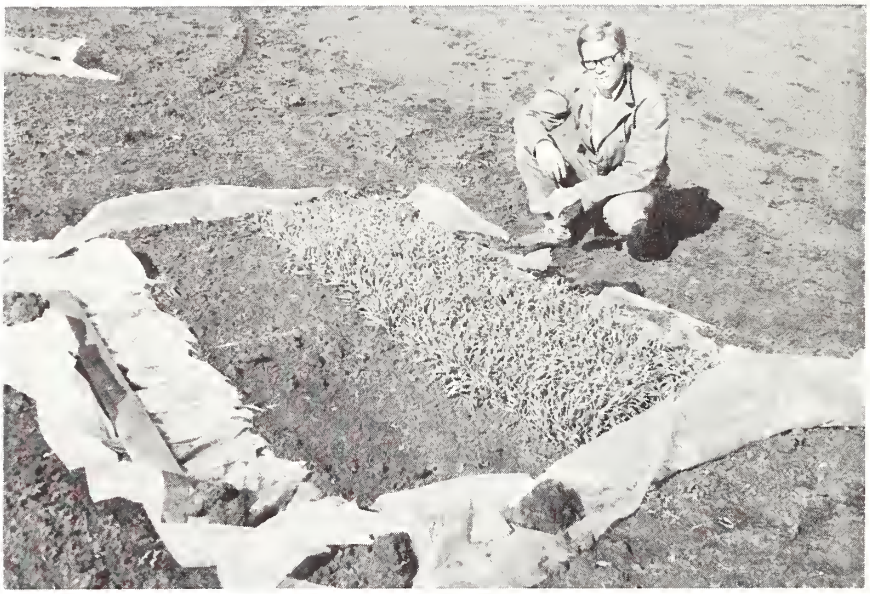


Fig. 53. Snapshot of plot used to discover the role of transpiration in water loss of peat. Rye plants are used to induce wilting.

TABLE 63. INDUCED HEAT DRYING EXPERIMENT - FIELD 7E
AUGUST - SEPTEMBER, 1967

DPTH. INCHES	% MOISTURE (DRY WT.)		INCHES OF WATER PER FOOT		% MOISTURE AT TIME OF PLOT ESTABLISHMENT	INCHES OF WATER PER FOOT AT TIME OF ESTABLISHMENT	RAINFALL FOR PLOT DURATION (INCHES)		INCHES OF WATER PER FOOT OF RAIN PLUS ORIGINAL MOISTURE.		DURATION OF PLOT (DAYS)	TOTAL WATER LOSS INCHES OF WATER PER FOOT.		WATER LOSS PER DAY EXPRESSED IN INCHES PER FOOT	
	CROP	BARE	CROP	BARE	(BOTH; DRY WT.)	(BOTH)	CROP	BARE	CROP	BARE		CROP	BARE	CROP	BARE
0-3	56.4	154.6	.92	2.51	274.6	4.46	1.76	1.50	6.22	5.96	34	5.30	3.45	.156	.101
3-6	61.8	183.4	1.00	2.98	282.7	4.60	1.76	1.50	6.35	6.09	43	5.35	3.11	.124	.072
	THE FOLLOWING PLOTS NOT WILTED														
(0-9)	TABULATED IN 3" INCREMENTS														
0-3	70.2	223.9	1.14	3.64											
3-6	74.1	263.5	1.20	4.28											
6-9	72.6	291.0	1.18	4.73											
AVERAGE MOISTURE VALUES FOR ENTIRE PLOT															
	72.3	259.5	1.17	4.22	313.0	5.09	1.76	1.50	6.85	6.59	45	5.68	2.37	.126	.053
(0-12)	TABULATED IN 3" INCREMENTS														
0-3	89.9	185.8	1.46	3.02											
3-6	97.9	223.1	1.59	3.63											
6-9	93.6	227.6	1.52	3.70											
9-12	98.0	243.8	1.59	3.96											
AVERAGE MOISTURE VALUES FOR ENTIRE PLOT															
	95.0	220.1	1.54	3.58	330.9	5.38	1.76	1.50	7.59	7.33	45	6.05	3.75	.136	.082

Density of all plots 8.5 lb/ft^3 (.1355)gm/cc as determined by volumetric cores and coated displacement samples.
All plots sampled four times-above data averaged from multiple samplings.
Plot planted to rye watered (.26") on 8-30-67.
3" isolation plot wilted 9-11-67; 6" isolation plot wilted 9-20-67.

On 22 September, both the 9 and 12 inch plots were excavated and similarly tested. These plots were considered near the permanent wilting percentage. The data in Table 6.5 shows the results.

The moisture content of all samples are expressed on the dry weight and volume basis. Moisture loss under cropped conditions represents evaporation and transpiration, while that lost on adjacent bare areas represents only evaporation. Under crop cover, the rate of water removal (inches water/day) was higher in the three inch plot, signifying more intensive root activity per unit volume under a semi-restricted root zone. There is not a significant difference in water loss per unit time between the 6, 9, and 12 inch plots.

On the adjacent bare areas, a significant mulch effect of the surface took place. The rate of moisture loss on these plots was greatest in the three inch zone, because of the shallower depth of moist peat below the surface "mulch", which was approximately 1/2" in all plots.

A comparison of water removal by a cropped versus a bare surface gives a good indication of the significance of this network of plots. The average rate of water removal under bare conditions was .077 in/ft./day, while that under a cover of grass averaged .136 in./ft./day.

The total water lost during the control period by a cropped versus a bare surface, accounting for precipitation, was 5.60 in. water/ft. under grass and 3.17 in. water/ft. with a bare surface. The above two sets of figures are averages of total water lost, in inches per foot of peat, for all four depths of isolation.

Those plots on which the grass wilted, the 3 and 6 inch depths, contained .92 and 1.00 in./water/ft. respectively, while the adjacent bare plots contained 2.51 and 2.98 in./water/ft. At the 6 and 9 inch levels, plots under grass at time of harvest contained 1.17 and 1.54 inches of water/ft. for their entire depths respectively, while comparable bare plots had 4.22 and 3.58 inches of water per foot of peat.

The preceding data clearly shows that transpiration exceeds evaporation alone for this series of plots. The effect of surface mulching on bare sites is also shown to be quite significant. Any procedure of water removal by isolation should utilize shallow depth procedures to partially alleviate the recharge effect from depths below 2 or 3 inches. However, at the three inch depth of isolation, with a bare surface, the plots measured a net loss of just .51 inches of water over a period of 34 days, excluding any precipitation. A method such as this, then, may only be expected to efficiently remove water when just the surface 1 - 1½ inches are isolated, with provisions for the exclusion of precipitation.

Temperatures for this period were low 70° F. maximums and high 30° F. minimums for August, and mid-60° F. maximums to high 20° F. minimums for the month of September.

Tabulated data for this experiment will be found in Table 63

14. Wood content of peat

The amount of wood contained in peat is of great concern to a peat operator as the wood, like other extraneous material, must be removed from the peat before bagging the final product for sale. It is both difficult and costly to remove wood either in the field or in the processing plant. For this reason estimates were made of the wood content of peat in the upper 48 inches of the deposits in several fields at the Wilderness Valley Experimental Farm.

Method -- Twelve inch cubes (1 cu. ft.) of peat were excavated intact at 12 inch intervals - 0-12, 12-24, 24-36, and 36-48 inches. These were wrapped with poly sheeting and weighed.

The wood particles were carefully and completely removed from the cube of peat. They were then submerged in a container full of water and the amount of water displaced was recorded. This value was used to calculate the total volume of a cubic foot that is occupied by wood.

The wood was dried to determine the weight per cubic foot.

Results -- The data on wood content in peats from several fields at out peat experiment station on both the volume and weight basis are shown in Table 64.

The content of wood in peats in all fields and at all depths was much lower than had been anticipated from visual observations. Estimates from visual observations had varied from 20 to 30 percent but this data shows the highest percentage of wood to be 13.7% by volume in the 24-36 inch layer of one of the samples taken from Field 9.

The surface layers of peat in all fields (0-12") averaged less than 1.0% wood by volume. The layer in peats with the highest wood content was the 24-36 inch zone although the average wood content was less than 8.2% by volume.

The deepest strata (36 to 48") was similar in root content to the surface peat and averaged less than 1% wood by volume.

TABLE 64. WOOD PERCENTAGE IN PEAT FROM SELECTED FIELDS AT WILDERNESS VALLEY FARMS

	FIELD 6-E		FIELD 6-W		FIELD 7-E		FIELD 7-W	
Dept;h(in)	(% by Vol.)	(lb/Ft^3)	(% by Vol.)	(lb/Ft^3)	(% by Vol.)	(lb/Ft^3)	(% by Vol.)	(lb/Ft^3)
1-12	.4	.06	1.0	.16	.2	.02	1.7	.38
1-12	1.0	.20	.4	.13				
1-12	1.5	.22	.9	.22				
1-12	.3	.06	1.2	.22				
1-12	2.1	.37	.8	.16				
(average)	1.1	.18	.9	.18	.2	.02	1.7	.38
12-24	2.0	.28	.9	.13	2.8	.53	.6	.09
12-24								
12-24								
(average)	2.0	.28	.9	.13	2.8	.53	.6	.09
24-36	7.7	1.00	7.1	.63	8.2	.94	6.9	1.16
24-36								
24-36								
(average)	7.7	1.00	7.1	.63	8.2	.94	6.9	1.16
36-48	.9	.13	1.4	.17	.1	.03	1.1	.13
36-48								
36-48								
(average)	.9	.13	1.4	.17	.1	.03	1.1	.13

TABLE 64. (Continued)

Depth (in)	FIELD 8-C (% by Vol.)	FIELD 8-C (lb/Ft^3)	FIELD 8-W (% by Vol.)	FIELD 8-W (lb./Ft^3)	FIELD 9 (% by Vol.)	FIELD 9 (lb/Ft^3)	FIELD 10 (% by Vol)	FIELD 10 (lb/Ft^3)	BASIC AREA (% by Vol)	BASIC AREA (lb/Ft^3)
1-12	.3	.09	.9	.19	.2	.06	.4	.08	.4	.03
1-12					.9	.19			.4	.06
1-12-					.4	.09				
1-12										
1-12										
(average)	.3	.09	.9	.19	.5	.11	.4	.08	.4	.05
12-24	.6	.06	1.6	.34	1.4	.22	1.0	.16	8.0	1.16
12-24					3.9	.61	3.2	.44	3.0	.38
12-24					1.8	.25			.9	.13
(average)	.6	.06	1.6	.34	2.4	.36	2.1	.30	4.0	.56
24-36	1.9	.22	3.1	.59	9.6	1.19	6.9	..75	5.2	.59
24-36					13.7	1.53	5.9	.31	3.0	.31
24-36					.7	.16			5.0	.59
(average)	1.9	.22	3.1	.59	8.0	.96	6.4	.53	4.4	.50
36-48	3.25	.44	.6	.09	5/3	/25	1.7	.31	4.7	.63
36-48					3.7	.44	1.9	.25	1.6	.22
36-48					1.2	.13			4.1	.44
(average)	3.25	.44	.6	.09	3.4	.27	1.8	.28	3.5	.43

Conclusions -- These data indicate that wood in peat of this type does not occur in any great quantity and its removal in processing should not be too costly.

15. Mechanical dewatering of peat

The techniques for mechanical dewatering peat using hydraulic presses, commercial dewatering V-type presses and applied suction show much promise for an economical peat operation. Although the research undertaken was not complete in all respects the experimental results with such devices is included in this report. The basic principle involved with these kinds of processes are described under the headings of peat compression studies, Davenport Machine and Foundry Co. mechanical dewatering tests, and a proposed operation using hydraulic ram presses.

The advantages of using mechanical dewatering devices are as follows:

1. All year production is assured instead of seasonal operation as with a conventional field harvesting operation.
2. Clearing, ditching and field preparation costs are much less.
3. Smaller size bog can be used.
4. Uniform product produced.
5. Quality of product is superior because fibers are not destroyed as with field harvesting where machinery is a factor.
6. Peat readily rewets since it is not excessively dried at any time.

Laboratory Report from Davenport Machine and Foundry Company, Davenport, Iowa

Materials Tested: The materials were received in twelve (12) 55 gallon barrels and consisted of: 4 barrels of sphagnum moss peat, 4 barrels of Reed-Sedge Peat and 4 barrels of washed Reed-Sedge Peat. The Reed-Sedge Peat came from the Experiment Station at Wilderness Valley Farms.

Machinery Used: "Davenport" Continuous Mechanical Dewatering Press -- Type 3A; Rotary Flash Dryer with Discharge Hood - 18" Dia. x 10' - 0" long.

Moisture Analysis: Davenport laboratory and laboratory at Wilderness Valley Farms. Data used is from the Wilderness Valley Farms laboratory.

I. Pressing Tests

A. Operating Conditions - 3A Press
1. Method of Feed: Shoveled and tamped into open spout
2. Disc Speed: Approximately 1 RPM or 20 RPM on pinion shaft
3. Amperage Pull
    a. Empty press - 2 amps.
    b. Loaded press - 3 amps.
4. Drive Rating: 5 H.P. motor - 6.8 amps. maximum

B. Sampling Conditions
1. Samples Taken
    a. Entering press
    b. Leaving press
2. Production Run

C. Pressing Test No. 1
1. Material: Washed Reed-Sedge Peat from Wilderness Valley Farms
2. Moisture:
    a. As received: 91.3%
    b. After pressing: 81.6% - 1st run, 82.4% - 2nd run
3. Production Run: 146# in 6 minutes or 1460#/hour of pressed material
4. Weight per cubic foot wet: 62#

D. Pressing Test No. 2
1. Material: Reed-Sedge Peat from Wilderness Valley Farms
2. Moisture:
    a. As received: 85.5%
    b. After pressing: 84.3%
3. Production Run: 139# in 6 minutes or 1390#/hour of pressed material
4. Weight per cubic foot wet: 58#
5. Remarks: Material did not press well due to its slippery nature caused by high amount of fine material

E. Pressing Test No. 3
1. Material: Sphagnum Moss Peat
2. Moisture
    a. As received: 93.1%
    b. After pressing: 80.1%
3. Production Run: 142# in 6 minutes or 1420#/hour of pressed material
4. Weight per cubic foot
    a. Wet: 60#
    b. Pressed: 27#

II. Drying Tests

A. Operating Conditions - Rotary Flash Dryer
1. Dryer Drum RPM: 24
2. Intake Conveyor RPM: 16
3. Inlet Temperature: 1000° F.
4. Outlet Temperature: 220° F.

B. Sampling Locations
1. Press outlet
2. Dryer outlet

C. Drying Test No. 1
1. Washed Reed-Sedge Peat after pressing
2. Moisture
a. Wet Material: 82.4%
b. After Drying: Run once - 67.8%, run twice 34.8%
3. Remarks: More thorough washing would result in better drying

D. Drying Test No. 2
1. Material: Sphagnum Moss Peat after pressing
2. Moisture:
a. Wet material: 80.1%
b. After drying: 50.3%
3. Material temperature at discharge: 136° F.
4. Weight per cubic foot
a. After pressing: 27#
b. After drying: 9.5#

E. Remarks
1. Feed and temperature of dryer are variable which allows for regulation of the product
2. Product is very uniform

III. Results and Conclusions

A. Pressing Tests
1. Water removed: 93.1 to 80.1
a. 949#/100# of solids (See Table 65)
b. Percent drop - 13%
c. Percent of water eliminated - 71.5%
2. Improved feed would result in drop to at least 75%
a. Additional water removed: 80.1 - 75.0, 103#
b. Down - screw feed at additional cost

B. Drying: Davenport Dryer 8' x 50'
1. Natural gas cost: Mesabi Iron Range
a. For 6 cu. ft. compressed bale - 85#, 30% moisture
(1) 80% feed - $.1303/bale
(2) 75% feed - $.0931/bale

TABLE 65. TABLE OF MOISTURE CONTENT SHOWING THE NUMBER OF POUNDS OF WATER FOR EACH 100 POUNDS OF DRY SOLIDS AT VARIOUS PERCENTAGES OF MOISTURE (WET BASIS)

Moisture,%	Water,lb.	Moisture,%	Water,lb.	Moisture,%	Water,lb.	Moisture,%	Water,lb.	Moisture,%	Water,lb.
1	1.01	21	26.6	41	69.5	61	156	81	425
2	2.04	22	28.2	42	72.3	62	163	82	455
3	3.10	23	29.9	43	75.5	63	170	83	490
4	4.16	24	31.6	44	78.6	64	178	84	525
5	5.26	25	33.3	45	82.0	65	186	85	566
6	6.40	26	35.1	46	85.0	66	194	86	615
7	7.54	27	37.0	47	88.7	67	203	87	670
8	8.70	28	38.9	48	92.3	68	212	88	735
9	9.90	20	40.7	49	96.0	69	222	89	810
10	11.10	30	42.9	50	100.0	70	234	90	900
11	12.36	31	44.8	51	104	71	245	91	1010
12	13.64	32	47.0	52	108	72	256	92	1150
13	14.94	33	49.4	53	113	73	270	93	1328
14	16.28	34	51.5	54	117	74	285	94	1565
15	17.65	35	53.9	55	122	75	300	95	1900
16	19.1	36	56.1	56	127	76	316	96	2400
17	20.4	37	58.8	57	133	77	335	97	3233
18	22.0	38	61.2	58	138	78	354	98	4900
19	23.5	39	64.0	59	144	79	376	99	9900
20	25.0	40	66.6	60	150	80	400	100	----

b. Lower costs for higher percent moisture products
2. Electric costs, etc. to be calculated

IV. PEAT PRODUCTION METHODS

A. Conventional production methods

The peat harvesting and production methods currently used by the peat industry vary with producers. Generally the larger producers use a conventional peat operation which is based on a large acreage of cleared and ditched peat lands with either vacuum or mechanical harvesting.

Such a method is described in detail in a report by Robert M. Brower dated December, 1966 which is included with this report.

Flow Sheet A shows the steps in peat production using this method. The peat may be either artificially dried using a rotary drier or baled directly from the harvesting fields when weather permits.

The advantages of this peat production method are that large acreages of land may be utilized by using a number of harvesters and hence the production may be very great -- as much as 500,000 to 1,000,000 six cubic feet (standard compressed) bales per year. Also most of the larger operators in the U. S., Canada and Europe use this method and hence the technology is well known to those in the industry. Most of the problems have been overcome over the years during the time this method was being developed. The result has been a relatively uniform quality peat product, standardization of bale sizes, and interchange of production information.

The main disadvantages with the field harvesting method are the total dependence on good harvesting weather and seasonal nature of the operation. Also the quality of the product when artificially dried is lowered markedly so that consumers frequently complain about the rewetting potential of the product.

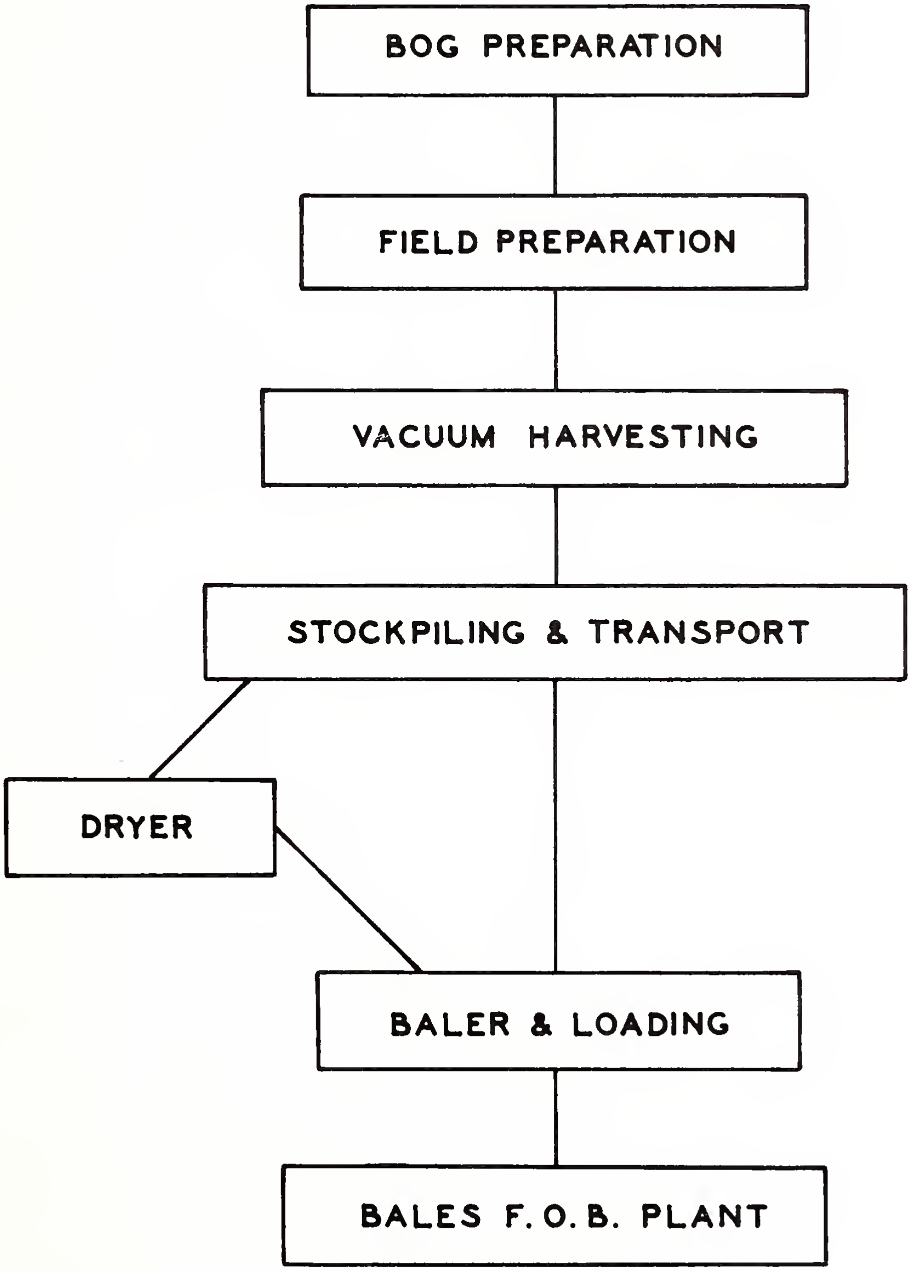
This report on a conventional peat operation gives a description of methods of bog preparation such as clearing of land, ditching, plant construction, materials movement systems, and equipment needed for a large scale operation -- 600,000 bales per year. It also gives the projections of costs and shows a typical budget for a peat operation harvesting Sphagnum moss peat.

The details on costs and projected returns are very complete in all respects. This information should be highly valuable to prospective producers to help in planning and financing a new peat operation.

Flow Sheet "A"

"A"

CONVENTIONAL PEAT PRODUCTION METHOD



In the conclusions of this report, Mr. Brower lists the reasons for most of the failures in the peat business:

1. Inadequate financing
2. Trying to buy time with money
3. Locating an operation on a bog with inferior quality peat or insufficient reserves.

In addition to these reasons one might add that lack of technical knowledge and poor management may also lead to failure in a peat enterprise.

B. Alternative production method using mechanical dewatering

Mechanical dewatering of sphagnum peat is feasible using continuous dewatering presses in a large-scale batch-type peat operation. The function of the presses is to reduce the water content of peat to a level where it is economically feasible to the desired level by use of a rotary direct fired dryer.

In computing production costs for a commercial operation producing 500,000 bales per year, the following factors must be taken into consideration:

1. The presses must be large enough to handle sufficient quantity of peat in a continuous batch-type operation.
2. Material handling systems such as conveyors must be adequate to handle the large volume of material.
3. The rotary direct fired dryer must be both efficient and economical as well as be large enough to handle large volumes of peat.
4. Digging equipment must be capable of collecting 250,000 yards of wet peat per year. This is equivalent to 500,000 bales.

The cost of plant and harvesting equipment using "Davenport" dewatering presses and a large rotary dryer in a commercial operation are given below. Also costs on a single bale basis are computed and itemized. These costs reflect harvesting, conveying, drying, baling, loading, bag costs, amortization of plant and equipment, royalty on peat, administration, and sales costs. These cost figures are based partly on actual labor and equipment costs as well as estimates extrapolated from values furnished by companies presently producing peat of a similar type. Since these cost figures are estimates at best, they should be used only as a guide in determining production costs for a commercial peat operation.

COST OF PLANT AND HARVESTING EQUIPMENT USING "DAVENPORT DEWATERING PRESSES AND ROTARY DRYER IN A COMMERCIAL PEAT OPERATION

Plant and warehouse including buildings for presses and dryer (Modified from "Brower" Report)	$204,480
Dryer installation complete (8' dia. x 50' lg.)	100,000
Presses - Three 1A type (Davenport Co.)	50,000
Conveyors from field	70,000
Bog preparation - initial	35,000
A - frame screen and Trommel screen	8,000
	$467,480

Note: The clearing of the bog and harvesting to the conveyor will be calculated by using figures that would be paid if the work was done by an independent contractor. These figures will be shown in the breakdown of the cost per bale of peat by this operation for a plant with an annual capacity of 500,000 bales per year of 6 cu. ft. compressed size.

COST OF ONE 6 CU. FT. COMPRESSED BALE OF SPHAGNUM PEAT (30% moisture, wt. 80 lbs.)

Bog preparation - amortized/bale			$ .012
Harvesting cost - drag line (to conveyor)			.08
Labor - Conveyor, A-frame and Trommel			.029
Drying and Pressing -	Natural gas	.093	
	Electricity	.025	
	Labor	.084	.202
Baling and loading ("Brower" Report)			.17
Cost of bag and board " "			.46
Royalty (State-owned land)			.02
Amortization of plant and equipment (20 years)			.055
Administrative (insurance, maint., etc.)			.129
Sales cost (10% of 1.95)			.195
	Total		$1.352

Unit Price $1.352/6 cu. ft. bale

Note: Sale price of $1.95 for a 6 cu. ft. bale f.o.b. plant is taken from "Brower" Report.

Net before taxes -- 500,000 $1.95 - 1.352 = 299,000
(Based on 500,000 bale/year operation of 6 cu. ft.)

CONCLUSIONS: The production costs given above should be compared to those given in the conventional method by Mr. Brower. No field drying is necessary using this type of operation and, therefore, harvesting is possible all year instead of seasonally. As far as we know, no operation of this type has been perfected at present but indications are that with continued research on this method the technological problems can be solved and economical operation of this type can be developed.

HIGH COMPRESSION BALES

Materials movement system by passing a dryer and utilizing a high pressure hydraulic ram to compress bales with at least 4 to 1 compression is shown in flow sheet B.

Estimates on the production costs for such an operation are listed below:

Cost of Equipment Using Dewatering Presses
and Hydraulic Ram Compression Baler

Capital Investment Costs:

Bog Preparation initial stage	$35,000
A-Frame screen and trommel screen	8,000
V-type dewatering presses (3)	50,000
Conveyors and vibrating screen	70,000
Buildings	50,000
Hydraulic Ram Presses (3)	25,000
Loading Conveyors	20,000
Miscellaneous Equipment	5,000
Unforeseen	5,000
Capital Total	$268,000

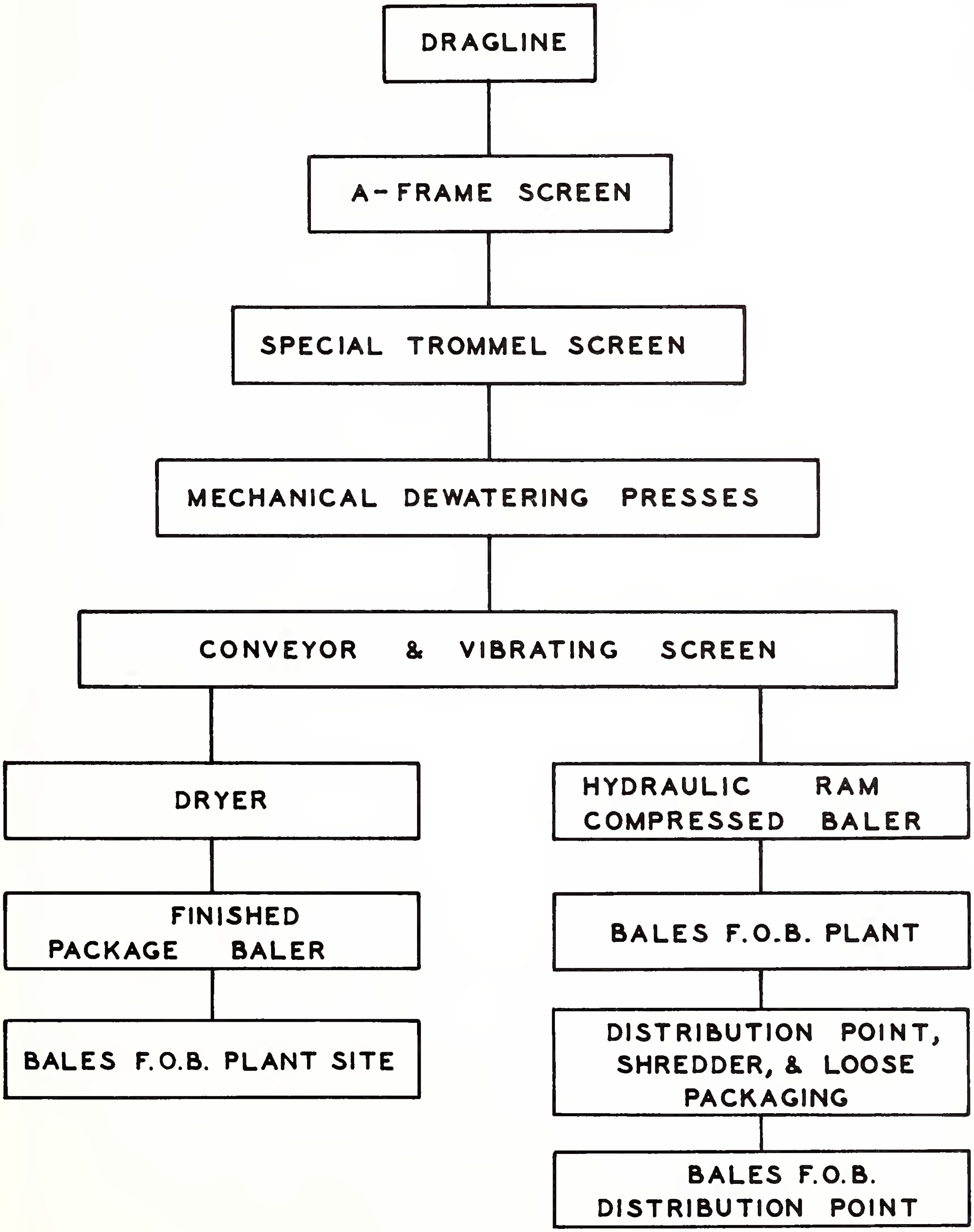
Production Cost Per Bale (250,000 - 4/1 compressed)

Bog preparation (20-year amortization) (Additional preparation and conveyors)	$ .03
Harvesting - drag line	.16
Labor - screening and conveying	.12
Labor - presses	.16
Compressed baling and loading	.12
Amortized plant and equip. (20 years)	.09
Administrative costs (salaries, insurance)	.26
Sales costs	.20
Cost per Bale Total	$1.14

Flow Sheet "B"

"B"

PROPOSED PEAT PRODUCTION METHOD


DRAGLINE
A-FRAME SCREEN
SPECIAL TROMMEL SCREEN
MECHANICAL DEWATERING PRESSES
CONVEYOR & VIBRATING SCREEN
DRYER
FINISHED PACKAGE BALER
BALES F.O.B. PLANT SITE
HYDRAULIC RAM COMPRESSED BALER
BALES F.O.B. PLANT
DISTRIBUTION POINT, SHREDDER, & LOOSE PACKAGING
BALES F.O.B. DISTRIBUTION POINT

Calculating a projected sale price for a 6 cu. ft. 4 to 1 compressed bale of $1.75 f.o.b. plant site the net returns before taxes for a production of 250,000 highly compressed bales would be $152,500 per year. Sale price of $1.75 - $1.14 cost equals a net return per bale of $.61.

Freight costs would be considerably less per bale if computed on basis of the following:

Consider 4/1 compression ratio:

Original volume weight = 3 lb/cu. ft.
Compressed volume weight = 12 lb/cu. ft.
Percent water in original peat = 93.0%
Percent water in compressed peat = 70.0%

Total weight of a 6 cu. ft. compressed bale equals 240 lbs. at 70% water. A regular 41' 6" freight car will hold 500 6 cu. ft. volume bales. 500 x 240 = 120,000 pounds total weight per car.

Using the above figures it can be calculated that 500 of the highly compressed bales is equivalent to 1000 of the standard 2/1 compressed 6 cu. ft. Sphagnum moss bales currently enjoying the largest share of the market. For this size of car the cost per ton rate is slightly above one half the rate for a freight car with 500 standard bales. This means that in equivalents of standard 6 cu. ft. bales the per bale cost is reduced to slightly above one-half the present rate using conventional loading and 2/1 compressed bales. Thus, a savings in freight cost, which is the highest single cost item to a consumer, would be an added inducement to brokers and wholesalers buying peat produced by this method.

The bales would be loaded in freight cars with only wire around them and sent to several centrally-located distribution points. At these distribution points the highly compressed bales could be sold as packaged to large users such as greenhouse growers, nurserymen, etc. who have the equipment to refluff the peat by shredding the compressed bales. In this manner a high quality peat moss product would be available for their specialized uses.

Other compressed bales would channel into warehouses where it would be refluffed by shredding, then baled or bagged loose and sold to the retail outlets. Although the exact retail price for such a peat product has not been computed in this report it would be considerably below the present retail outlet price because of the savings in freight costs, harvesting and process costs, etc.

This production method might be particularly applicable to barge or boat shipping via the Great Lakes route to Chicago, Cleveland, New York or to other centrally located distribution points near large population centers.

V - ADDENDUM

MARKETING AND DISTRIBUTION
OPPORTUNITIES
FOR
MINNESOTA PEAT

W. B. Saunders & Company
Economic Consultants
Washington, D. C.

December 1965

This study was accomplished by professional consultants under contract with the Economic Development Administration. The statements, findings, conclusions, recommendations, and other data in this report are solely those of the contractor and do not necessarily reflect the views of the Economic Development Administration.

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I. Introduction

This report summarizes the research conducted by the designated project team in accordance with a contract between the State of Minnesota, Department of Iron Range Resources and Rehabilitation and the contractor. The objectives of this project were to determine a marketing program for Minnesota peat. More specifically, the project included a detailed examination of present transportation, distribution and marketing practices for domestic and imported peat and an evaluation of the market which Minnesota producers should penetrate.

The Conclusions and Recommendations and Detailed Findings evaluate (1) the product, (2) its market, and (3) the marketing framework.

II. Conclusions and Recommendations

A. Product

Sphagnum peat offers the most advantageous marketing opportunity for Minnesota peat producers.

1. Sphagnum has an average retail price per loose cubic foot of 29¢ - 36¢ versus 56¢ for reed-sedge;
2. A bale of sphagnum yields 3 - 4 times the coverage of a comparable weight of reed-sedge;
3. Sphagnum transportation costs are lower because of its 2 1/2 to 1 compression ratio, thereby allowing shipment to more distant markets;
4. Sphagnum can be pelletized at a 6 to 1 compression ratio.

B. Market

The market for all types of peat is expanding in the United States. By 1963 U. S. peat consumption attained 808,000 tons for a ten-year increase of 75 per cent. Because imported peat sales have remained fairly stable in recent years, domestic peat has captured the increased market share and in 1963 accounted for 547,000 tons or 68 per cent of U. S. consumption.

It is significant that reed-sedge and humus producers have captured about 83 per cent of this market. Reed-sedge sales have shown the greatest advance because the Michigan producers have actively developed the market for their product. Sphagnum producers, on the other hand, have not exploited their real market potential. Of the U. S. sphagnum producers, most are small and poorly organized, serving only local and regional markets; Canadian exporters of sphagnum, however, have effectively reached U. S. East and West Coast markets favorably located to their production centers.

Orderly pricing attempts by the Canadian and Michigan producers have been instrumental in their market development. Minnesota sphagnum producers should strive for a similar policy. In all markets surveyed reed-sedge commanded a higher price per loose cubic foot than did sphagnum. Oddly enough, the domestic producers of sphagnum reportedly do not make a concerted effort to obtain a price that represents a true value relationship for their product. In part, this lack of endeavor to realize parity is explained by the fact that production costs and, even more so, transportation costs, are lower for sphagnum than for reed-sedge. However, market analysis indicates that Minnesota sphagnum can realize an f.o.b. plant price at \$2.20 for an 85-lb bale, which compares with 14.66¢ per loose cubic foot at the 2:1 compression ratio and 18.3¢ per loose cubic foot at the 2.5:1 compression ratio.

In the detailed findings documented in the following chapters, the market potential available to Minnesota is relatively large. Within the next five years annual sales of approximately 135,000 tons to 177,000 tons of Minnesota sphagnum could be attained in selected markets.1/ Indications of competitors' attitudes on the one hand and the growing national demand for peat on the other, lead to the conclusion that a production and marketing program along the lines recommended in this report stand a very reasonable chance of success.

C. Marketing

Peat producing centers in Minnesota will have to organize their marketing efforts and strategy along lines similar to those followed by the Canadian exporters and the large Michigan producers. First of all, it will be necessary to develop brand acceptance and loyalty at the retail level through distribution and local cooperative advertising. Second, the distribution system should be organized, installed, and strictly enforced, whether brokers and/or distributors are used. Once the demand for Minnesota peat is created at the retail level, it can be sold through any marketing channel. But, if the stability of price and the long-term demand for sphagnum is to be developed, the selected marketing channel must be followed consistently.

As mentioned earlier, the marketing system followed by most small domestic producers is somewhat erratic and suffers from a lack of organization which works to the disadvantage of both the producer and the consumer. Specifically, the avoidance of middlemen has not necessarily resulted in a lower-cost product to the consumer and yet it has not raised the net price obtained by the producer.

The sphagnum package must be attractive to the consumer and fully spell out sphagnum's greater coverage capability per bale and its soil improvement qualities and characteristics. Pressure upon producers by large-scale retail outlets, such as supermarket chains, has resulted in a proliferation of brand names and varieties of labels which in many cases do not even properly describe the product packaged in an attractive bag or bale. The trade practices, supervised and regulated by the Federal Trade Commission, appear to be insufficiently developed and/or enforced. The American Society for Testing and Materials and its advisors are attempting to gain acceptance for tighter regulations which could either be voluntarily accepted by members of the industry or enforced by the regulatory agencies.

1/ There are twenty-five 85-lb bales per ton; therefore, these selected markets represent a potential of 3,258,800 to 4,164,700 bales annually.

Sphagnum producers should carefully pinpoint their markets and be selective in their mode of transport. A 19-state market between the Rocky and Appalachian Mountains offers the most realistic potential for Minnesota producers. Through freight equalization via the railroads (see Detailed Findings) Minnesota sphagnum producers should be able to capture a major portion of this 19-state market. Freight equalization refers to charging a consistent price in all markets and utilizing the higher profit on short hauls to defray the transport cost to distant markets. However, advantage should be taken of gypsy truckers and backhauls whenever possible as this mode of transport is known to be a key factor in the distribution of Michigan peat. Recognizing that a loose cubic foot of sphagnum weighs only about 25 per cent of the weight of a loose cubic foot of reed-sedge, it is understandable that a producer might be willing to pass on his transportation cost advantage to the ultimate consumer. However, the consumer should be educated to the fact that sphagnum has greater coverage value per dollar than reed-sedge so that he will want to buy sphagnum.

D. Reed-sedge

In view of technological research now underway concerning the economics of harvesting and producing reed-sedge in Minnesota, it may be that forthcoming results will considerably reduce production costs and thereby increase the competitive position for Minnesota reed-sedge producers. If, for example, a real breakthrough in drying techniques will come about, then the cost of producing and distributing Minnesota reed-sedge would be substantially reduced.

Because of greater consumer acceptance for reed-sedge -- brought about by an aggressive promotion program under the brand name, "Michigan Peat"--a lower cost reed-sedge has a dual advantage -- namely, the lower cost per se and the lesser promotion cost than that applicable to sphagnum. In conflict with the foregoing, it must be pointed out that, if the lower production costs brought about by technical breakthroughs are also applicable to Michigan-produced reed-sedge, the relative position for these two origins might remain the same as it is now. In short, they would then have to share markets which are equidistant to both.

III. Detailed Findings

A. Product

1. Types

Peat is partially decomposed vegetable matter which has accumulated under water or in a water saturated environment. Federal specifications classify peat in four types: (1) sphagnum-moss peat, (2) other moss peat, (3) humus peat, and (4) reed-sedge peat.

Sphagnum-moss peat is formed mainly of several species of sphagnum mosses. It is usually loose, spongy and often layered and varies from light grayish brown to deep brown in color. The other moss group is made up principally of disintegrated hypnum plants, often associated with other mosses. Generally brownish in color, hypnum peat is also light, porous and spongy. Humus (frequently called "muck peat") peat includes all peat so decomposed that its biological identity cannot be determined. Reed-sedge peat is formed primarily from various reeds, sedges, and associated swamp grasses and plants. Peats of this type are heavier, contain a higher moisture content and are rusty brown or frequently blackish in color.

In this report, both of the moss types will be referred to as sphagnum and the term reed-sedge will include humus peat.

Virtually all peat is excavated by conventional types of earth-moving machinery. However, a few producers have specially designed equipment similar to the types used at large operations in Canada and Europe. Peat is prepared for sale by drying, shredding, screening, and packaging (except for local bulk sales). Because the use of peat is highly seasonal, the producers' shipping season is primarily from January through May, with lesser amounts shipped in the early fall. During this period of time he must package and ship the peat he removed from the bogs during the previous summer. The peat is generally stockpiled adjacent to the processing plant and is bagged or shipped in bulk as orders are received for the product. Relatively small inventories of bagged peat are kept on hand at the plants.

2. Common Denominator

A common basis for comparison of reed-sedge and sphagnum must be developed to make this report meaningful. Although these two major peat types have similar uses, several of their characteristics are quite dissimilar. The significant differences are that reed-sedge is not compressible and has a high moisture content (about 65%) whereas sphagnum is compressible to about 2 or 2-1/2 to 1 and has a low moisture content (about 35%). The significant implication in these product differences is that sphagnum is a lighter weight bulkier product when loose. Therefore, when sphagnum is used in the garden, the amount of coverage per cubic foot is much greater.

For the home gardener or ultimate user, the advantages of sphagnum should be of great interest. First, a bale of sphagnum will have from 3 to 3-3/4 times as many loose cubic feet of peat as a bag of reed-sedge. This range depends on whether the sphagnum is compressed at 2 or 2-1/2 to 1. Moreover, a loose cubic foot of sphagnum costs only 29¢ to 36¢ versus 56¢ for reed-sedge. These prices are based on the average 1965 retail prices throughout the United States; to the homeowner, sphagnum was 55.5 to 92 per cent lower in cost (per loose cubic foot). The vital comparative statistics are shown below:

	Sphagnum Peat	Reed-Sedge Peat
Package	85-lb bale	100-lb bag
Moisture content	35%	65%
Contents of package	12 to 15 cubic feet -- loose	4 cubic feet -- loose
Average retail price	$4.34	$2.25
Average retail price per loose cubic foot	$0.29 to 0.36	$0.56

The obvious conclusion relative to consumer's cost should also be viewed from the producer's point of view. Transportation costs compare as follows:

	Sphagnum	Reed-Sedge
Weight per loose cubic foot, lb.	5.66 to 7.084	25
Advantage as % of weight	22.6 to 28	100

3. Packaging

Prior to the widespread use of polyethylene and poly-lined kraft papers, peat moss was baled under compression and shipped in burlap reinforced with wooden slats. This burlap bale was inadequate for prolonged storage because the inherent acidity of the peat moss, when combined with moisture, caused the disintegration of the burlap cover; also the bale did not stand up under frequent handling.

The development of strong multiwall bags poly-coated both inside and outside and more recently, large heavy-gauge full poly bags have transformed the packaging of peat. These new containers maintain the peat quality and minimize loss or spoilage in handling. From a marketing viewpoint, they permit multi-color printing, an attractive point to retail sales. This durable and attractive packaging has greatly expanded the retail sales distribution through new outlets such as grocery chains.

Essentially there are no well-established producer labels. Private brands are predominant. Individual producers with modern packaging equipment pack many different labels in the course of a season. It is common to find five or six different brands of identical peat in a single market all packed by the same producer.

Prior to 1955, most domestic peat was sold in bulk. However, by 1963, 51 per cent of the total U.S. peat was sold in packages. The rapid increases in packaged sales in recent years (see Table 1) has resulted, as mentioned, from the development of inexpensive synthetic film moisture-proof bags. Packaged peat presently is sold principally to nurseries and greenhouses for use in growing plants and shrubs, to landscape gardeners and contractors for building lawns and golf course greens, and to garden, chain, hardware, and variety stores for ultimate sale to homeowners.

Table I

Commercial Sales Of Peat In The United States[1/]

Packaged Peat	1961 Tons	1963 Tons	Per Cent Change 1961-63
Sphagnum	41,297	44,898	8.7%
Reed-Sedge	158,271	212,784	34.4%
Humus	6,546	19,786	202.3%
Reed-Sedge & Humus	164,817	232,570	41.1%
Total	206,114	277,468	34.6%
Bulk Peat			
Sphagnum	66,307	47,909	-27.7%
Reed-Sedge	81,181	92,921	14.5%
Humus	132,824	128,323	-3.4%
Reed-Sedge & Humus	214,005	221,244	3.4%
Total	280,312	269,153	-4.0%
Grand Total	486,426	546,621	12.4%

1/ Excludes imported peat which is virtually all packaged.

Source: U. S. Bureau of the Census, Minerals Yearbook, 1961 and 1963.

Sphagnum is generally compressed into a bale at the ratio of 2 to 2-1/2 to 1. For example, a 6-cubic-foot compressed bale, at a compression ratio of 2 to 1, would contain 12 loose cubic feet of sphagnum and at a 2-1/2 to 1 ratio would contain 15 loose cubic feet of sphagnum. It is important to note that a sales unit (package) of sphagnum is described by volume rather than weight.

A typical multiwall, poly-coated paper, or straight polyethylene bag for a 6-cubic-foot bale has the following dimensions prior to filling: Length, 50", depth, 14-1/2", width, 18-1/2" (7-3/4 cubic feet).

Sphagnum compressed bales are sold in the following sizes:

Seven and one-half (7-1/2) cubic feet	-	(nursery size)
Six (6) cubic feet	-	(standard bale)
Four (4) cubic feet	-	
Three (3) cubic feet	-	(half bale)
One (1) cubic foot	-	(suitcase bale)

Reed-sedge is packaged loose because it is not readily compressed. Because of a typical 65 per cent moisture content, reed-sedge peat requires a moisture-proof container to prevent package deterioration. The first use of polyethylene for packaging reed-sedge peat was in the form of lightweight liners which were enveloped by burlap sacks. While the liner reduced package deterioration, the retailers consider the burlap unattractive. As a result poly-laminated multiwall and polyethylene bags offer an optimum package as a moisture barrier and as a merchandising aid for reed-sedge.

Reed-sedge is sold in the following sizes:

Cubic Feet	Weight		
4.0	100 lb.	-	burlap with poly-liner, poly-laminated multiwall and polyethylene bags
3.2	80 lb.	-	poly-laminated multiwall and polyethylene bags
2.0	50 lb.	-	poly-laminated multiwall and polyethylene bags
1.0	25 lb.	-	poly-laminated multiwall and polyethylene bags
0.5	10 lb.	-	polyethylene bag
0.25	5 lb.	-	polyethylene bag

Reed-sedge is sold on a weight basis in contrast to sphagnum which is sold on a compressed cubic foot basis.

Preliminary research has determined that it is possible to form pellets made up of different peat types in combination form. These pellets have certain excellent characteristics which are:

1. Uniformity of size and weight.
2. Uniform density.
3. The capability of re-wetting.
4. A size and shape which permits application to a lawn surface by means of a standard fertilizer spreader.
5. Dimension and density which permits the use of common mechanical methods for packaging and handling.

From research now completed, it has been found that a pellet which meets acceptable standards of uniformity, size and density, can best be formed by combining sphagnum peat moss, reed-sedge peat and a binder to which a wetting agent has been added. This pellet is formed according to the following ratio of ingredients:

1. 4 parts - sphagnum peat moss.
2. 4 parts - reed-sedge peat.
3. 1 part - binder (such as a garden compost).

A pellet 1/8 inch in diameter by 1/4 inch in length is the desirable size.

Preliminary tests have indicated that the following comparisons exist between peat pellets as heretofore described, and regular sphagnum peat moss, as found in compressed bales.

Unit description:

Sphagnum peat moss	6 cubic feet compressed bale, containing 15 loose cubic feet of peat moss.
Peat pellets	2-bushel bag containing 2-1/2 cubic feet of pellets.

The sphagnum peat moss unit effectively covers 180 square feet of surface mixed into the soil at the rate of one inch of peat to three inches of soil. This coverage is recommended in directions printed on the package now being sold.

Two and one-half cubic feet of pellets effectively cover 240 square feet when mixed into soil at the rate of 1/8 inch of pellets to 3 inches of soil.[1] These research tests have shown that pellets expand to 2-1/2 times their original size in approximately six hours when re-wetted.

The following data are of interest:

1. Net weight of one cubic foot damp mix at approximately 60% moisture, prior to pelletizing - 18.625 lb.

2. Ratio of cubic volume pellets to mix after extrusion - .55 to 1.

3. Cubic volume of pellets from 1 cubic foot mix after drying to approximately 15% moisture content - .30 cubic feet.

4. Net weight of pellets after drying, from 1 cubic foot of mix - 7.625 lb. (.3 cubic foot of pellets).

Extending the above data, a 2-bushel (2-1/2 cubic foot bag) of pellets would weigh 63.5 lb., covering 240 square feet versus 85 lb. of compressed sphagnum covering 180 square feet, a weight/value relationship of 1 to 1.78.

Preliminary cost studies indicate that total production costs for this product will be approximately $1.25 per unit -- including packaging and a plant overhead factor of 15 per cent.

Basic merits of this product are:

1. The volume of pellets required to accomplish the same job for which one bale of sphagnum is needed weighs approximately 50 lb. less. This results in a reduction of transportation and handling costs.

2. In-plant handling costs of the finished product are considerably less than the costs for handling raw peat.

3. Peat pellets provide the consumer with a product uniform in size, simple to apply, and relatively free from dust and dirt.

For reasons which are not obvious to us, commercial pelletized peat production has not yet been attempted. It is suggested that perhaps one of the stumbling blocks is represented by the need to combine two types of peat. All commercial peat producers are limited to one type of peat at any one of their plants.

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[1] Based on experience gained from research conducted at Wilderness Valley Farms Research Center, Zim, Minnesota

Minnesota's large contiguous deposits of both sphagnum and reed-sedge provide an ideal situation for overcoming the mix discrepancy prevailing at existing plants.

Because of the distinct advantages pointed out, it is to be hoped that the development of commercial pelletizing activities shall be given a high priority.[1]

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[1] Reliable sources indicate that Canadian sphagnum producers are making research and development advances on pelletized peat.

4. Bulk

Bulk shipments of sphagnum peat over any appreciable distance are not feasible because of the low load density of only 7 lb./cu.ft. Assuming a 2,800 cubic foot car, the total load weight would be only 19,600 lb. Because compression to at least one-half the loose volume is feasible when packaged, sphagnum should be compressed to reduce shipping costs. Presently, however, there is no known method of compressing sphagnum to any appreciable degree in standard transportation equipment suitable for movement in bulk. Further factors which would inhibit bulk shipment are:

1. The individual fibers of sphagnum peat tend to stick together. Hence, if it were loaded in hopper cars, it would tend to bridge across a hopper opening and it would be difficult and costly to unload.

2. Pneumatic equipment for loading and/or unloading could not be used because the blower would clog and the abrasiveness of the product would quickly wear out the equipment including the rail car or truck body.

Reed-sedge is not subject to the same bulk shipment limitations. Reed-sedge peat generally weighs about 25 lb./cu.ft. and flows more easily than does sphagnum. Nevertheless, reed-sedge peat does cling together. One could, however, load a hopper or gondola car (assume a cubic capacity of about 2,800 cu.ft.) to the substantial weight of about 70,000 lb. This peat could be loaded in an open-top car and covered with polyethylene film. However, because of the low value of bulk reed-sedge peat, it cannot absorb the (relatively) high transport costs per unit of product.

Most of the bulk peat sold is either reed-sedge or humus. It is sold either by the cubic yard or by the ton. It is consumed in locations quite close to the origin, usually within a 25 mile to 50 mile radius.

B. Market

1. Sales

Peat sales have risen sharply over the decade from approximately 460,000 tons in 1954 to 808,000 tons in 1963. Although sales of both domestic and imported peat have expanded, the domestic production has accounted for the major share of the increase. In fact, during the 1960 to 1963 period domestic peat made all the gains while peat imports declined slightly as shown below.

	Tons (000)			
Sales	1960	1961	1962	1963
Total	695	745	834	808
United States	431	493	566	547
Imports	264	252	268	261

The decline in peat sales in 1963 reportedly was caused by heavy rainfalls in the producing areas. However, the long-term trend indicates a continued increase because of the rapid expansion of the home and garden market.

Because the homeowner has become a major factor in the market, it is important to note the distribution or mix of packaged and bulk sales of domestic peat.

	Sales of Domestic Peat			
	Total	Bulk	Packaged	
	Tons (000)	Tons (000)	Tons (000)	Bales or Bags (000)[1/]
1963	546	269	277	7,387
1962	567	268	298	7,947
1961	486	280	206	5,493

In 1962 and 1963 packaged peat sales exceeded bulk shipments. Moreover, peat package sales increased about 35 per cent from 1961 to an estimated 7.4 million units in 1963. Bulk sales are discussed further in the "Uses" section.

Reed-sedge and humus peat have dominated the U. S. domestic sales and have gained a steady increase in the market share as shown in the following analysis.

1/ Based on an average weight of 75 lb per bale or bag.

	Sales of Domestic Peat - Tons (000)					
Type	1961	% of Total	1962	% of Total	1963	% of Total
Total	486	100	569	100	546	100
Reed-sedge and humus	379	78	462	82	454	83
Sphagnum	107	22	107	18	92	17

The large share of reed-sedge and humus producers is accounted for by two major factors. First, polyethylene packaging materials developed in the 1950's made it possible to greatly expand the distance reed-sedge could be shipped and provided access to new and larger channels of distribution such as retail chains. Second, the Michigan reed-sedge producers instituted a major marketing program oriented to the retailer and consumer. The reasons for the success of reed-sedge sales are also explained in the "Packaging and Advertising" sections.

2. Projected Sales

Several "variables" must be taken into consideration in the projection of the market for domestic peat, such as transportation costs, competition and consumption data. Because the data from which a projection can be developed is limited, it has been necessary to utilize unconventional methods of calculation based on reasonable assumptions and careful investigations.

Physical observation and inquiries with the major peat producers confirmed that they are logically concentrating their sales efforts in those markets to which transportation costs are the least. The Michigan producers, for example, extend their market as much as possible by taking advantage of backhaul and the use of gypsy truckers. Due to this situation the market reach and distribution pattern have an erratic quality and make it quite infeasible to project which distant markets the Michigan producers will capture for themselves at any one time.

Conversely, there are approximately 22 states in which the Michigan and Minnesota producers have a geographic advantage over their competitors except for the producers located in some of these states. Of these, Wisconsin and Indiana produce more than they consume; hence, they must be excluded. Colorado, Illinois and Ohio consume more than they produce and therefore this net requirement is considered a potential for Michigan or Minnesota. In summary then, from Minnesota's point of view, the 22 geographically advantageous states are reduced to 16 states in which all of the market represents a potential and three states in which the excess of consumption over local production represents a potential (the grand total of 19 states includes the State of Minnesota and excludes the State of Michigan).

Bearing in mind that sphagnum has an implicit transportation cost advantage and pursuing the objective of developing a market for sphagnum at stable and approximately equal prices throughout the Minnesota potential market area, we can project the market potential based on a principle of freight equalization.

Let us assume that Minnesota sphagnum peat will sell at $3/bale delivered in the marketplace (on a loose cu ft basis, this compares with a price of $0.89 for a 4 cu ft bale of reed-sedge peat which is well below the lowest wholesale price reported at $1.20). Assuming that the producer needs a minimum of $2.20 per bale f.o.b. plant ($2 being the base price and allowing up to 10 per cent for promotion and advertising), this then would provide a balance of 80¢/bale for transportation and brokerage. If brokerage is 5 per cent of the delivered price or 15¢/bale, then the net amount available for freight is 65¢/bale. The average of 65¢/bale transportation cost will in some markets be exceeded and, in others, the actual cost will be less.

Using the domestic consumption figures of domestic peat for 1961 in the 19 states, as previously explained, and applying rail freight costs from Duluth to each state and its consumption, we arrive at a total transport bill. If we then divide by the total quantity we obtain an average freight cost per bale (normal procedure for obtaining a weighted average). Adding to this calculation the brokerage fee @ 5 per cent of delivered cost, we arrive at a weighted average for freight and brokerage. Table 2 contains the consumption figures for each of the 19 states and the combined freight and brokerage costs, and the resulting weighted average of 71¢/bale. Now, it can be seen that the theory of a $3 delivered price and a net f.o.b. plant price of $2.20 can be supported for the entire 19-state market area.

Obviously, the same transport cost averaging can be applied by any competitor whether from within the 19 states or from outside, including the Canadian producers. Our research of present and past marketing practices do not, however, support the contention that any one of the large producers is prepared to approach or in fact is approaching his marketing policy from that point of view. Although a freight equalization and delivered price equalization policy could be initiated by Minnesota's competitors, as said, it is our view that if this were to happen it might at most affect the Minnesota potential temporarily but benefit the entire peat industry due to the stabilization of the price structure it would cause.

Table 2 also includes projections of the consumption in the 19-state area. They are based on a 4 per cent growth rate and a 7 per cent growth rate, ranges of high and low which appear reasonable to us. The totals of these projections for the year 1970 show a potential of 135,000 short tons and 177,000 short tons respectively.[1]

It should be noted that published statistics provide the basis for projecting the growth rate in the number of households during the 11 years 1959-1970 as 20.3 per cent and the consumption of peat per household over the 11 years at a rate of 27.9 per cent. Hence, the compounded growth rate for total consumption of both domestic and imported peat would be approximately 4 per cent annually. This growth rate, however, must be adjusted by the decline in imported peat and the accompanying increase in domestic peat sales which indicates an annual growth rate for domestic peat of 7 per cent. In allowing for a 4 per cent to 7 per cent growth rate on the national basis, we have not taken into consideration that consumption per household as reported in 1961 was 27.3 lbs while in the 19-state area it was only 18.2 lbs. In other words, if the per household consumption in the 19-state area were to increase so as to approach the national average, the potential for Minnesota would be approximately 50 per cent larger than the figures stated in Table 2. Not having any data which might support the thesis that the average per household consumption in these 19 states will in fact accelerate to somewhere near that of the nation as a whole, we have disregarded this potential in the calculations. However, it can be considered as a valid reserve which might offset some of the expressed potential lost to producers in other states who might adopt the freight equalization policy.

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[1] This potential of 3 to 4 million bales would require 6 to 7 peat plants producing about 500,000 bales annually.

Table 2

Estimated Total Market Potential for Peat in a 19 State Area Favorable to Minnesota Producers[1]

States	Consumption of Domestic Peat Tons 1961[2]	Freight plus Brokerage Cost/85 lb bale	Consumption of Domestic Peat Tons @ 4% Growth		Consumption of Domestic Peat Tons @ 7% Growth	
			1965	1970	1965	1970
Minnesota	2,087	$ .39	2,464	2,970	2,882	3,894
Illinois	8,477	.55	10,080	12,150	11,790	15,930
Ohio	36,434	.55	43,456	52,380	50,828	68,676
Iowa	6,504	.55	7,728	9,315	9,039	12,213
Wyoming	101	.68	112	135	131	177
Nebraska	348	.68	448	540	524	708
Kansas	1,277	.68	1,568	1,890	1,834	2,478
Missouri	9,246	.68	10,976	13,230	12,838	17,346
Kentucky	7,673	.68	9,184	11,070	10,742	14,514
Alabama	775	.98	896	1,080	1,048	1,416
Tennessee	3,302	.98	3,920	4,725	4,585	6,195
Mississippi	36	.98	42	51	50	67
Louisiana	619	.98	672	810	786	1,062
Arkansas	190	.98	224	270	262	354
Oklahoma	2,643	.98	3,316	3,780	3,668	4,956
Colorado	812	.98	1,008	1,215	1,179	1,593
Texas	9,337	1.26	11,088	13,365	12,969	17,523
New Mexico	1,232	1.26	1,456	1,755	1,703	2,301
Arizona	2,782	1.26	3,360	4,050	3,930	5,310
Total	93,875	.71[3]	111,818	134,781	130,788	176,713

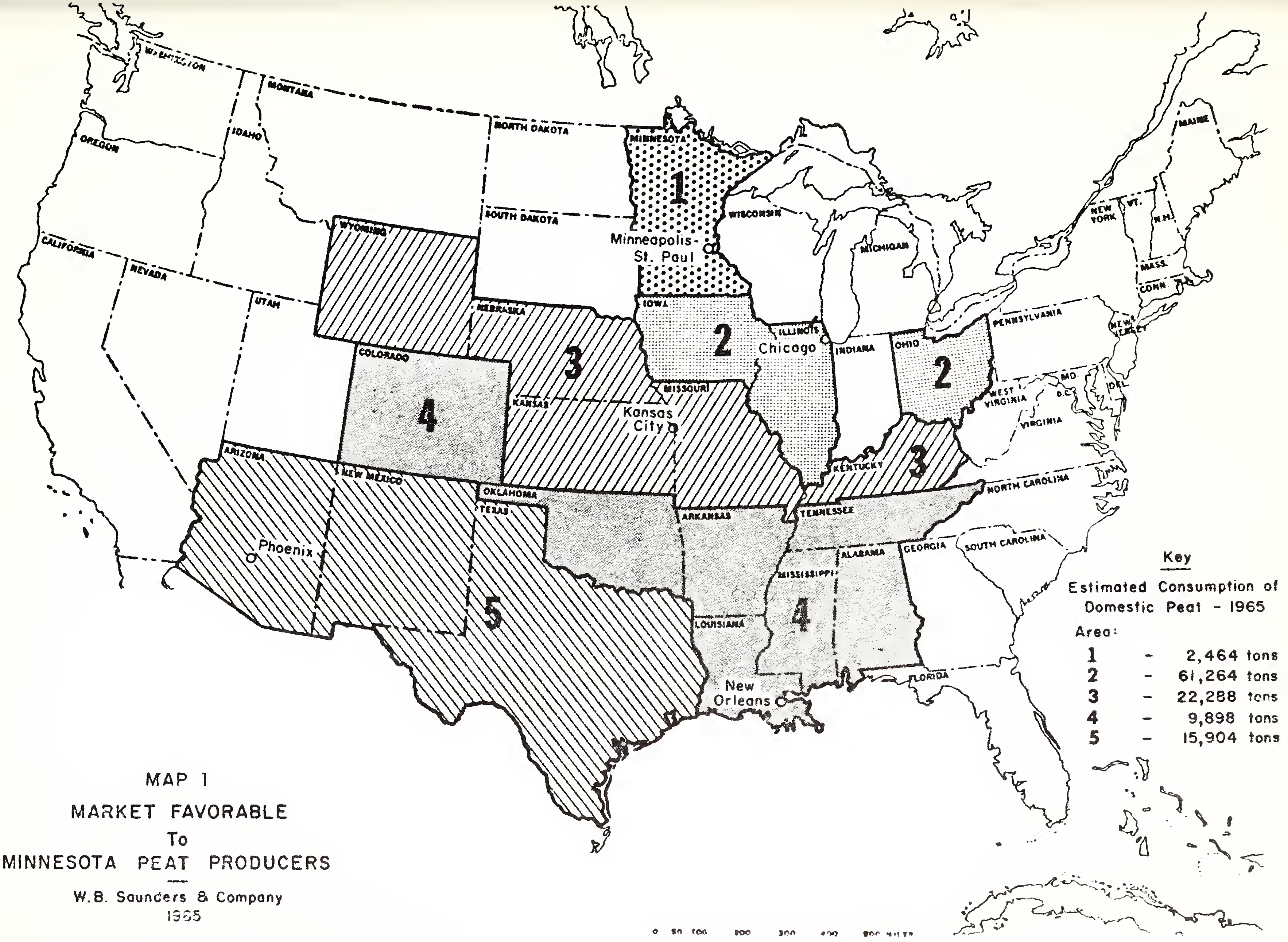
1/ For theory see chapter description.

2/ Net consumption excluding production within each state.

3/ Weighted average for 19 states.

Finally, it should be noted that the freight equalization approach does not imply that the Minnesota producers should not take advantage of any backhaul opportunities or generally of the least expensive mode of transportation that may become available from time to time. The marketing plan which results in the market potential arrived at is only sound when it is based on the knowledge that calculated transport costs to each of the markets will be available continually. To illustrate, if the producer spends $1.26/bale for a shipment to Arizona, he knows that he can recover the excise over the allowable average from shipments, for which transportation will cost less than 71¢/bale.

Following is Map 1 showing the states most favorably located for the sale of Minnesota sphagnum. While in all cases the entire state has been indicated, it must be understood that certain fringe areas are likely to be favorable to local or regional producers. These states have been divided into five geographic groupings and the tonnage potential of each group is also indicated.



MAP 1
MARKET FAVORABLE
To
MINNESOTA PEAT PRODUCERS

W.B. Saunders & Company
1965

3. Competition

There are known peat deposits in at least 35 states, and total U.S. reserves have been estimated at approximately 14 billion short tons of air-dried peat. Eighty-nine (89) per cent of the reserves are in four states -- Minnesota, Wisconsin, Florida, and Michigan. Minnesota's reserves, estimated at approximately 6.8 billion tons, represent nearly 50 per cent of the United States total. Table 3 contains a summary of U.S. peat reserves by producing states. Peat deposits can be found throughout most of Minnesota, but more than three-fourths of the state's total reserves, 5.1 billion tons, are in the four northern counties of Beltrami, Koochiching, Itasca, and St. Louis. Minnesota has large and high quality deposits of both sphagnum and reed-sedge peats.

In spite of the fact that Minnesota has about one-half of the nation's total peat reserves and almost all of the commercially harvestable U.S. sphagnum deposits, Minnesota ranks quite low in production. Recent production has been concentrated mainly in the states of California, Indiana, Michigan, Pennsylvania, and Washington. Collectively, these five states have one-half of the total operations (67 producers) and about three-fourths of the total U.S. output (440,000 tons in 1963). Obviously, Minnesota's reserves to date have not been developed to the same extent as in other states.

In the twenty-five states (see Table 3) there are 140 producers. Twenty-four of these states have a total of 100 reed-sedge and humus producers and 14 states have moss operations. Nine operators produce reed-sedge or humus and moss peat. In addition, in twenty-four states, 128 producers sell in bulk and in nineteen states 53 producers sell packaged peat. Forty-one producers sell bulk and packaged peat.

Until recently, little was known about the specific locations and quality of the Minnesota deposits. Exhaustive tests conducted at the University of Minnesota have conclusively established that Minnesota bogs have sphagnum peat moss and reed-sedge of a quality equal to that produced anywhere in the world.

Under the direction of the Commissioner of the I.R.R.R.C. of the State of Minnesota, surveys have been conducted in detail to ascertain the location and extent of various peat deposits in northeastern Minnesota. These surveys have determined that there are numerous deposits, large in size and high in quality, available for exploitation. These deposits are, in some instances, primarily sphagnum peat moss and in other cases, primarily reed-sedge peat.

Prior to World War II there were less than 100 U.S. producers. Because of packaging limitations, it was not practical to ship domestic peat over any great distance. This led to bulk shipments to nurseries, landscape gardeners and other large users. For example, in 1955, 83 producers were in operation harvesting 273,669 short tons. At this time polyethylene started to advance the packaging art and domestic producers

Table 3

Peat Operations by States 1964

State	Reserves at (000) Tons		Producers				
	State Total	Active Operations	Total	R1/	S2/	Bulk	Pkg.
California	22,000	15,885	5	4	1	5	2
Colorado	n.a.	4,044	14	7	9	14	1
Connecticut	2,000	272 est.	1	1	--	1	--
Florida	2,000,000	822	7	7	--	7	--
Georgia	n.a.	3,046 3/	2	1	1	2	--
Idaho	n.a.	340	2	2	--	1	--
Illinois	10,000	1,270	5	3	2	5	1
Indiana	13,000	1,122	8	2	6	8	3
Iowa	22,000	2,790	2	1	1	2	1
Maine	100,000	3,805	3	--	3	--	3
Maryland	n.a.	3,046 3/	2	2	--	2	2
Massachusetts	12,000	1,600 est.	2	2	--	2	1
Michigan	1,000,000	23,060	29	23	7	26	16
Minnesota	6,835,000	14,642	8	3	5	6	5
Montana	n.a.	167 4/	1	1	--	1	1
Nevada	n.a.	167 4/	1	1	--	1	--
New Jersey	15,000	2,040 est.	2	2	--	2	1
New York	480,000	932	5	5	--	5	2
North Dakota	n.a.	167 4/	1	1	1	1	--
Ohio	50,000	525	8	5	4	8	1
Pennsylvania	2,131	2,131	10	10	3	9	6
South Carolina	n.a.	3,046 3/	1	1	--	1	1
Vermont	8,000	36	3	3	--	2	2
Washington	n.a.	1,997	15	12	4	15	2
Wisconsin	2,500,000	848	3	1	2	2	2
25 States	13,121,131	87,800	140	100	49	128	53

1/ Includes reed-sedge and humus.

2/ Moss, including sphagnum.

3/ Includes Maryland, South Carolina and Georgia @ 9,138 divided by 3 equals 3,046.

4/ Includes Montana, Nevada and North Dakota @ 499 divided by 3 equals 167.

Source: Mineral Industry Surveys, 1965.

could then compete in more distant markets. By 1960, there were 115 producers with a combined total production of 470,889 short tons, an increase of 72 per cent. By 1963, production amounted to 546,621 short tons, a further increase of 12 per cent.

While the competition is strong in numbers of producers, there does not seem to be any price cutting in sphagnum, such as exists with reed-sedge peat. Geographical location of producing and market areas contributes to part of the pricing structure.

Many local producers fail to properly label, or otherwise identify, their product. Frequently reed-sedge or humus is referred to as peat moss. The major producers of reed-sedge peat, such as the Michigan Peat Company and the Anderson Peat Company of Michigan, the Millburn Peat Company of Indiana, the Vita Peat Company of California, and the Western Peat Company of Colorado try to maintain an approximate 25-pound-per-cubic-foot volume/weight basis, whereas many smaller producers do not. Moisture content is difficult to control and strictly enforced standards have never been part of the industry. Presently the Peat Producers' Association of the United States is trying to establish quality standards for the industry. This should work to the advantage of any existing or potential producer in Minnesota, due to its uniform quality of peat deposits.

Production and sales of peat, by state, for the years 1959 and 1963 are shown in Tables 4 and 5 respectively. The magnitude of the increase in Michigan and Canadian sales and the decrease in European sales is clearly shown in Chart 1.

In recent years, the predominant source of sphagnum has been Canada, followed by West Germany -- other sources have contributed little to the total import tonnage (see Tables 6 and 7).

The Canadian producers are located in British Columbia, Manitoba, Ontario, Quebec, and New Brunswick. The dominating companies, in descending order, are: Premier Peat Moss Co., Quebec; Western Peat Moss, Ltd., Manitoba, British Columbia, and New Brunswick (now a subsidiary of Redwing Peat Corp., U.S.); Atkins & Durbrow, Ltd., British Columbia and Ontario; Atlantic Peat Moss Co., New Brunswick; and Conrad Faford Co., Ltd., New Brunswick.

Sphagnum peat sold in the U.S. is principally of foreign origin (Canada and Europe). As a rule in North America, real sphagnum moss is restricted to an area north of a line reaching from south-central Maine through north-central New York to north-central Minnesota and British Columbia. Hence, most of the domestic peats are of the reed-sedge and humus varieties.

In dealing with European sources of peat moss, which primarily are located in West Germany, U.S. brokers book in advance such quantities of peat moss as they are able to accumulate orders for.

Table 4

Peat Sold In The United States, By States - 1959

States	In Bulk		In Packages		Total	
	Short Tons	Value	Short Tons	Value	Short Tons	Value
Alaska	--	--	--	--	--	--
California	17,389	$ 188,720	15,845	$ 228,435	33,234	$ 417,155
Colorado	6,674	35,488	--	--	6,674	35,488
Connecticut	2,065	12,605	25	500	2,090	13,105
Florida	34,446	158,139	--	--	34,446	158,139
Georgia	1/	1/	1/	1/	4,288	1/
Idaho	1/	1/	--	--	1/	1/
Illinois	7,706	43,327	1,411	28,217	9,117	71,544
Indiana	10,811	110,454	4,582	91,640	15,393	202,094
Iowa	--	--	--	--	--	--
Maine	--	--	1/	1/	1/	1/
Massachusetts	773	1/	--	--	773	1/
Michigan	82,461	465,904	97,408	1,624,638	179,869	2,090,542
Minnesota	--	--	--	--	--	--
New Hampshire	25	1/	--	--	25	1/
New Jersey	23,835	217,332	6,748	85,827	30,583	303,159
New York	10,050	86,000	1,516	33,400	11,566	119,400
Ohio	5,348	41,624	450	31,500	5,798	73,124
Pennsylvania	22,131	189,048	1,865	43,343	23,996	232,391
South Carolina	3,470	1/	724	1/	4,194	1/
Washington	32,884	123,586	--	--	32,884	123,586
Wisconsin	--	--	7,500	1/	7,500	1/
Undistributed	4,355	65,162	1,113	122,490	1,180	187,652
Total	264,423	$1,737,389	139,187	$2,289,990	403,610	$4,027,379

1/ Included with "undistributed" to avoid disclosing individual company figures.

Source: Bureau of the Census, Minerals Yearbook, 1959.

Table 5

Production And Commercial Sales Of Peat In The United States In 1963, By States

State	Active Plants	Production (Short Tons)	Commercial Sales		
			Short Tons	Value	
				Total	Average
California	5	43,873	39,873	$ 450,193	$11.29
Colorado	5	13,774	13,774	97,724	7.09
Connecticut, Maine, Massachusetts	5	4,941	4,441	58,938	13.27
Florida	7	22,143	21,049	129,380	6.15
Georgia, Maryland, South Carolina	5	11,642	10,998	112,640	10.24
Idaho, Montana, North Dakota	3	2,070	1,320	24,550	18.60
Illinois and Iowa	4	21,732	21,732	239,939	11.04
Indiana	6	55,745	47,695	411,848	8.64
Michigan	28	255,859	251,809	2,412,995	9.58
Minnesota	6	8,373	8,110	294,373	36.30
New Jersey	3	23,685	23,685	241,042	10.18
New York	5	21,358	21,358	177,664	8.32
Ohio	10	7,110	6,910	108,876	15.76
Pennsylvania	7	44,910	33,952	338,667	9.97
Washington	11	38,648	37,248	187,549	5.04
Wisconsin	3	2,667	2,667	136,504	51.18
Total	113	578,530	546,621	$5,422,877	$ 9.92

Chart 1

U. S. Peat Consumption From Three Major Sources (for years indicated)

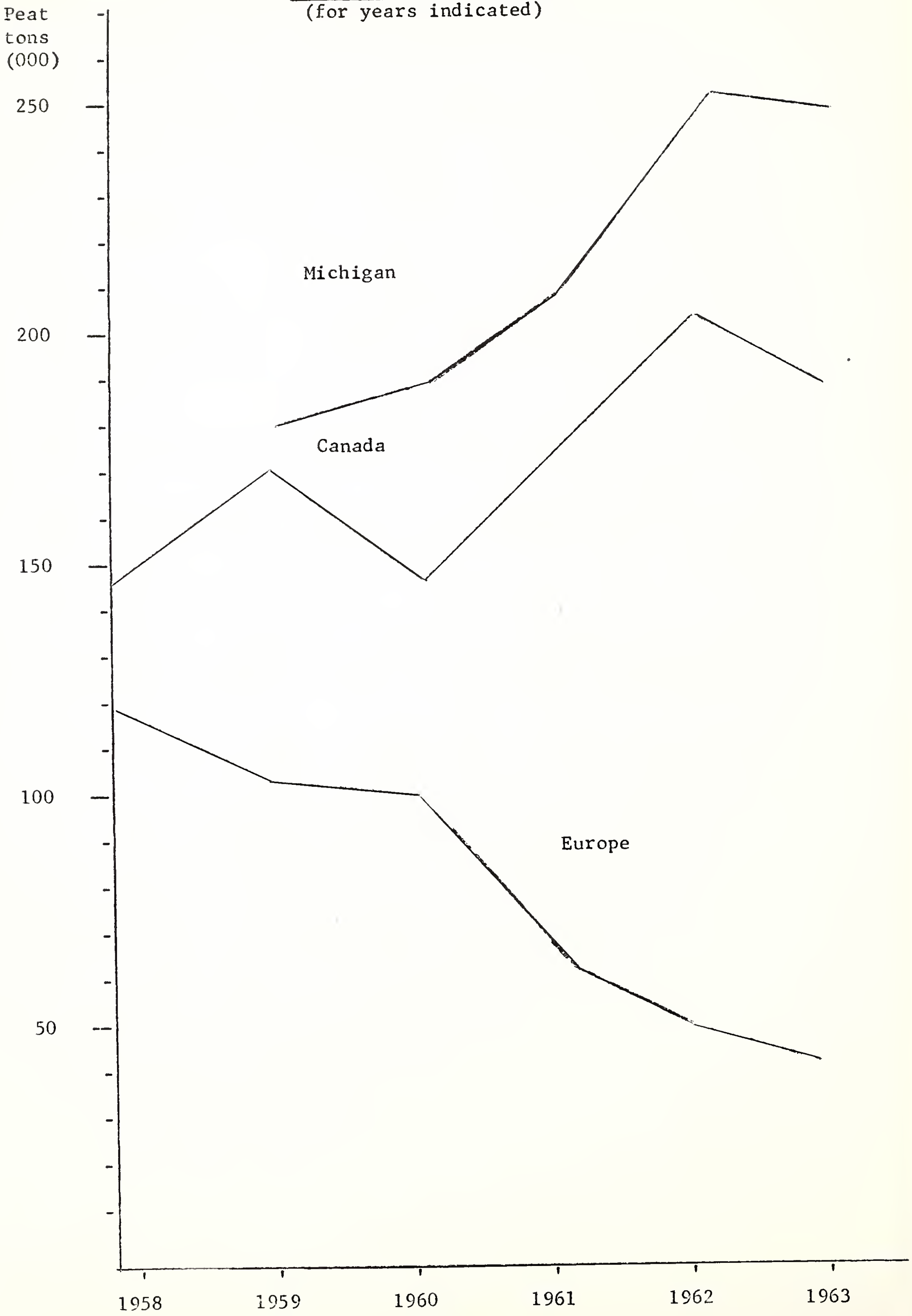


Table 6

Peat Moss Imported For Consumption In The United States, By Kinds And By Countries - 1960

Country	Poultry & Stable Grade		Fertilizer Grade		Total	
	Short Tons	Value	Short Tons	Value	Short Tons	Value
North America:						
Canada	5,593	$353,993	151,860	$ 8,918,092	157,453	$ 9,272,085
Mexico	25	915	-	-	25	915
Total	5,618	$354,908	151,860	$ 8,918,092	157,478	$ 9,273,000
Europe:						
Belgium-Luxembourg	-	$ -	46	$ 3,390	46	$ 3,390
Czechoslovakia	-	-	43	2,186	43	2,186
Denmark	-	-	5,553	256,204	5,553	256,204
Finland	-	-	83	2,944	83	2,944
Germany, West	3,303	131,836	80,282	3,108,597	83,585	3,240,433
Ireland	-	-	273	12,837	273	12,837
Netherlands	150	8,406	7,853	334,498	8,003	342,904
Norway	-	-	24	5,649	24	5,649
Poland & Danzig	-	-	8,120	332,235	8,120	332,235
Sweden	-	-	524	29,400	524	29,400
United Kingdom	-	-	132	5,342	132	5,342
Total	3,453	$140,242	102,933	$ 4,093,282	106,386	$ 4,233,524
Asia: Japan	12	2,371	1	120	13	2,491
Grand Total	9,083	$497,521	254,794	$13,011,494	263,877	$13,509,015

Source: Bureau of the Census, Minerals Yearbook, 1960

Table 7

Peat Moss Imported For Consumption In The United States, By Kinds And By Countries - 1963

Country	Poultry & Stable Grade		Fertilizer Grade		Total	
	Short Tons	Value	Short Tons	Value	Short Tons	Value
North America:						
Canada	4,135	$248,500	206,649	$10,038,335	210,784	$10,286,835
Guatemala	7	358	-	-	7	358
Mexico	40	4,239	-	-	40	4,239
Total	4,182	$253,097	206,649	$10,038,335	210,831	$10,291,432
Europe:						
Denmark	17	767	212	9,736	229	10,503
Finland	-	-	123	5,240	123	5,240
France 1/	-	-	7	368	7	368
Germany, West	1,273	55,440	34,099	1,411,885	35,372	1,467,325
Ireland	62	2,200	2,293	88,993	2,355	91,193
Netherlands	84	3,959	1,558	57,993	1,642	61,952
Poland & Danzig	-	-	6,786	247,017	6,786	247,017
Sweden	-	-	3,677	171,173	3,677	171,173
Portugal	-	-	124	2,000	124	2,000
United Kingdom	-	-	130	5,345	130	5,345
Total	1,436	$ 62,366	49,009	$ 1,999,750	50,445	$ 2,062,116
Asia: Japan	4	2,085	51	1,924	55	4,009
Grand Total 1/	5,622	$317,548	255,709	$12,040,009	261,331	$12,357,557

Average Value per ton $47.29

1/ Adjusted by Bureau of Mines.

Source: Bureau of the Census.

Usually, they will increase their orders somewhat in order to have sufficient amounts available to cover late orders and new business.

For a long time, this was a very orderly manner of doing business and maintained a stable market, both for quality and for price. As demand for peat moss increased, more individuals have entered the brokerage business and speculation has become a frequent occurrence. Peat moss entered the country without having been pre-sold. This, of course, leads to price instability and gluts of distress peat moss from time to time. However, as import freight and handling costs have increased and the Canadian industry has become a dominant source of supply, the problem of distress product from Europe flooding the market has now become a problem of the past.

4. Pricing

Packaged peat prices vary widely depending on transportation costs, origin and destination of shipments, the volume of the quantity purchased and the channel of distribution.

Table 8 below in general shows that retail selling prices are higher when the peat is shipped a greater distance such as Gary, Indiana to Dallas, Texas. However, the retailers' gross profit is higher as well. Of greater importance is the fact that the retail selling price and gross profit is highest in the case of a reed-sedge brand which has controlled (limited to select) distribution. By selective distribution, the pricing structure can be controlled and orderly.

In contrast, competition between regional producers has resulted in price cutting. This has worked to the disadvantage of the peat industry.

A typical reed-sedge price structure would be as follows (delivered from Copac, Michigan to Philadelphia, Pennsylvania) for a 100-lb bag:

F.O.B. plant	$ 0.85
Freight	0.575
Delivered price	1.425
Retail selling price	1.69'
Gross Profit to Retailer	15.8%

It will vary from market to market by the transportation cost element.

Another example of pricing to a specific market (Kansas City) of 6-cubic-foot compressed bales of sphagnum in a 500-bale single car delivery from Shelly, Manitoba would be as follows:

	Distributor	Markup on Del. Cost	Direct Chain	Markup on Del. Cost
F.O.B. plant selling price	$2.00	-	$2.00	-
Freight	0.86	-	0.86	-
F.O.B. destination	$2.86	-	$2.86	-
Brokerage - 5% selling cost	0.14	-	0.14	-
Distributor & chain cost	$3.00	-	$3.00	-
Distributor selling price:				
5-24 units	$3.90	30%		
25-49 units	$3.80	27%		
50-99 units	$3.70	23%		
100 or more units	$3.60	20%		
Retail selling prices	$4.95-$5.25	21%-32%	$3.99	33%

Table 8

Typical Reed-Sedge Pricing Structure

Origin	Destination	Cost and Price	Typical Bags of Reed-Sedge	
			100 lb	50 lb.
Michigan	Cleveland	F.O.B. plant	$0.85	$0.42
		Freight	0.74	0.37
		Delivered cost	$1.59	$0.79
		Gross profit margin (%)	0.30(15.9%)	0.19(19.4%)
		Retail price	$1.89	$0.98
Indiana or Colorado	Dallas	F.O.B. plant	$0.85	$0.63
		Freight	0.82	0.41
		Delivered cost	$1.67	$1.04
		Gross profit margin (%)	0.72(30%)	0.45(30%)
		Retail price	$2.39	$1.49
Colorado	Denver	F.O.B. plant	$0.85	$0.54
		Freight	0.50	0.25
		Delivered cost	$1.35	$0.79
		Gross profit margin (%)	0.34(20%)	0.26(24.7%)
		Retail price	$1.69	$1.05
			Controlled Reed-Sedge Label	
			80 lb	50 lb
Michigan or Indiana	Chicago	F.O.B. plant	$1.14	$0.76
		Freight	0.24	0.12
		Brokerage	0.07	0.45
		Distributor cost	$1.45	$0.93
		Delivery to dealer and dealer's profit	0.48	0.44
		Retailer's cost	$1.93[1]	$1.37
		Retailer's gross profit (%)	1.02(25.8%)	0.92(40%)
		Retail price	$3.95	$2.29

1/ Compare with $1.89 for 100-lb bag in chain store at Cleveland or $1.69 at Denver.

Grocery chains consider 25 per cent a good markup if the stock in a store turns once a week, but garden and nursery outlets strive for a 50 per cent markup on selling price.

The wholesale price of sphagnum (85-lb bale) has been found to vary from $2.75 to $3.10 and the retail price from $3.49 to $5.95 in 15 selected markets (Table 9). The wholesale price of reed-sedge (100-lb bag) has varied from $1.23 to $1.67 and the retail price has varied from $1.69 to $2.95 in these 15 cities.

It has been found that nearly all institutional users obtain their annual requirements on a bid basis. Many large private users require competitive quotations. As a result, the producer closest to the customer usually enjoys the business. Where point of delivery exceeds approximately 200 miles, the cost of transportation exceeds cost of product at plant. Consequently, origins and distance to market determine whether or not a producer can successfully compete in any given market.

The bulk prices for the producers (see Table 10) are on the average as follows:

Type of Peat	Price Per Ton
Moss (including sphagnum)	$8.28
Reed-Sedge	$8.48
Humus	$5.20

Most of the bulk sphagnum is sold locally to large users or to converters who package it for resale.

With the exception perhaps of reed-sedge peat, the increasing volume of sales in packaged form is of dual benefit to the peat industry. First, the margin of profit for packaged peat is higher than that sold in bulk and second, the increased volume permits larger investments in plant and equipment. The trend for increased use by house owners -- who use packaged peat exclusively -- is likely to continue and further benefit the industry.

Table 9

Representative Wholesale and Retail Prices in Selected Markets, 1965

City	Prices			
	Sphagnum (85 lb)		Reed-Sedge (100 lb)	
	Wholesale	Retail	Wholesale	Retail
Minneapolis-St. Paul	$3.00	$3.95 to $5.95	$1.20[1]	$1.89[1]
Chicago	2.85	3.89 to 4.95	1.59	1.89
Cleveland	2.85	3.89 to 4.95	1.59	1.89
Philadelphia	2.95	3.49 to 4.95	n.a.	n.a.
Kansas City	3.00	3.98 to 5.25	1.25	2.29
Washington/Baltimore	2.75	3.49 to 4.95	1.23	1.69
Atlanta	3.10	3.79 to 5.25	1.47	2.99
Phoenix	3.05	3.79 to 4.50	1.67	2.39
Houston	3.05	3.79 to 4.50	1.67	2.39
San Antonio	3.05	3.79 to 4.50	1.67	2.39
Dallas	3.05	3.79 to 4.50	1.67	2.39
New Orleans	3.05	3.79 to 4.50	1.67	2.39
Tulsa	3.10	3.79 to 4.95	1.50	2.95
Denver	2/	2/	1.35	1.69

1/ Sold in 50-lb bags; price of 50-lb bag × 2.
2/ Sphagnum was not found in this market.

Table 10

Commercial Sales of Domestic Peat in the United States in 1963, by Types of Peat and Their Uses

	Moss			Reed-Sedge			Humus			Combined
	Short	Value		Short	Value		Short	Value		Short
Use	Tons	Total	Average	Tons	Total	Average	Tons	Total	Average	Tons
Bulk:										
Soil Imprvmt.	45,264	$ 371,627	$ 8.21	85,539	$ 732,660	$ 8.57	124,515	$ 624,374	$ 5.01	
Other uses	2,645	24,937	9.43	7,382	54,973	7.45	3,308	42,713	11.22	
Total	47,909	$ 396,564	$ 8.28	92,921	$ 787,633	$ 8.48	128,323	$ 667,087	$ 5.20	269,153
	52%			30%			87%			
Packaged:										
Soil Imprvmt.	44,835	$ 870,721	$19.42	206,328	$2,092,554	$10.14	17,426	$ 166,824	$ 9.57	
Other uses	63	1,900	30.16	6,456	253,585	39.28	2,360	186,009	78.82	
Total	44,898	$ 872,621	$19.44	212,784	$2,346,139	$11.03	19,786	$ 352,833	$17.83	277,468
	48%			70%			13%			
Total:										
Soil Imprvmt.	90,099	$1,242,348	$13.79	288,957	$2,763,876	$ 9.57	141,941	$ 791,198	$ 5.57	
Other uses	2,708	26,837	9.91	16,748	369,896	22.09	6,168	228,722	37.08	
Grand Total	92,807	$1,269,185	$13.68	305,705	$3,133,772	$10.25	148,109	$1,019,920	$ 6.89	546,621
Percentage of:										
Total Short Tons	17%			56%			27%			
Total Value		23%			58%			19%		

Combined total value $5,422,877

Source: U. S. Bureau of Mines

5. Uses

Peat has been used throughout the world for agricultural, horticultural, and fuel purposes. In the United States, however, peat is used exclusively for agricultural and horticultural soil improvement purposes. The main benefits of peat application to soil are twofold. First, peat has moisture retention qualities which tend to keep the soil from drying out. Second, clays and other types of soils which become hard and difficult to work are loosened by the application of peat to the soil.

Peat application for lawns, gardens and general soil improvement is recommended by horticultural experts and peat producers on a volume basis rather than by weight.

It is commonly known that soil compacts after a period of time and requires some substance to make it friable and more productive. The U. S. Department of Agriculture (USDA) has strongly recommended the use of peat in soil conditioning in bulletin #290, August, 1933, "Grades of Peat and Muck for Soil Improvement", in bulletin #532, September, 1936, "The Comparative Moisture Absorbing and Moisture Retaining Capacity of Peat and Soil Mixtures", and in Farmer's Bulletin #2085, "Sphagnum Moss for Plant Propagation". A paper by Robert E. Lucas, Soil Service Dept., Michigan State University, published in March, 1961, develops in detail the benefits of peat as a soil amendment. Specific benefits pointed out are:

1. Increases moisture holding capacity of sandy soils.
2. Increases rate of water infiltration.
3. Makes fine textured soils more friable and better aerated.
4. Source of Nitrogen fertilizer.
5. Increases the exchange capacity of soil (buffering effect).
6. Increases the microbial activity.
7. Helps reduce the danger of soluble salt injury to plants.
8. Helps keep plant roots cool in the summer and warm in the winter, when used as a mulch.
9. Mulches help to prevent winter killing of ornamentals resulting from lack of water.
10. Acid peat mulches help control weed growth.
11. Acid peat improves growth of azaleas, rhododendrons, etc., which have a high iron and ammonia-nitrogen requirement.

Mr. Lucas in his article, "Peats for Soil Improvement," also points up the preferred type of peat for various uses:

Sphagnum Moss Peat:

- Mulching agent
- Potting soil mixes
- Soil aeration
- Liquid absorbent
- Litters
- For acid-loving plants

Reed-Sedge Peat:

- Lawn and flower bed soil mix
- Potting soil mixes
- Soil aeration

In the "Home and Garden Merchandiser", Dr. Rouse Farnham, Soils Department, University of Minnesota, states, "It is the function of peat, when added to soils, to increase the ability of soil to absorb water, provide for adequate oxygen and provide a mechanism by which plant nutrients can be held in the soil until needed. Soils needing organic amendments the most are densely compacted clay soils, very coarse sandy soils and all soils low in organic matter".

In "The Minnesota Horticulturist", March, 1962, Dr. Farnham states, "Peats in general have certain properties that make them valuable as garden soil improvers. One of the most important of these properties is high water-holding capacity. Peat added to coarse-textured soil, such as sand, provides adequate moisture reserves. Added to fine-textured (clay) and other hard-to-work soils, it makes them more open and porous, more retentive of moisture and generally more tillable.

"The base absorbing capacity of peat is an important property."

In the same article, Dr. Farnham included an analysis of the following peats:

Analyses of Common Horticultural Peats

Type of Peat	Range in ph	Range Water-Absorbing Capacity % Oven Dry	Range in Ash Content % Oven Dry	Range in Volume Wts. Oven Dry Lbs./Cu. Ft.	Range in Nitrogen % Oven Dry
Sphagnum Moss	3.0 - 4.0	1500 - 3000	1.0 - 5.0	4.5 - 7.0	0.6 - 1.2
Hypnum Moss	5.0 - 7.0	1200 - 1800	4.0 - 10.0	5.0 - 10.0	2.0 - 3.5
Reed-Sedge (Low Lime)	4.0 - 5.0	500 - 1200	5.0 - 15.0	10.0 - 15.0	1.5 - 3.0

Analyses of Common Horticultural Peats (continued)

Types of Peat	Range in ph	Range Water-Absorbing Capacity % Oven Dry	Range in Ash Content % Oven Dry	Range in Volume Wts. Oven Dry Lbs./Cu. Ft.	Range in Nitrogen % Oven Dry
Reed-Sedge (High Lime)	5.1 - 7.5	400 - 1200	5.0 - 18.0	10.0 - 18.0	2.0 - 3.5
Decomposed	5.0 - 7.5	150 - 500	10.0 - 50.0	20.0 - 40.0	1.5 - 3.0

The above quotations from these specialists in the field of soil science have had an impact on people interested or engaged in lawn and garden care.

Peat is sold in the United States for several purposes which are, in descending order of importance, soil improvement, potting soils, packing for flowers, shrubs, mushroom beds and in mixed fertilizers (See Table 11).

Table II

Commercial Sales of Peat in the United States in 1963, by Uses

Use	In Bulk			In Packages			Total		
	Short Tons	Value		Short Tons	Value		Short Tons	Value	
		Total	Average		Total	Average		Total	Average
Soil imprvmt.	255,318	$1,728,661	$ 6.77	268,589	$3,130,099	$11.65	523,907	$4,858,760	$ 9.27
Potting soils[1/]	5,169	31,588	6.11	6,718	410,831	61.15	11,887	442,419	37.22
Packing flowers, shrubs, etc.	4,176	36,427	8.72	2,161	30,663	14.19	6,337	67,090	10.59
Mushroom beds[2/]	1,426	14,034	8.84	--	--	--	1,426	14,034	9.84
In mixed fertilizers	3,064	40,574	13.24	--	--	--	3,064	40,574	13.24
Total	269,153	$1,851,284	$ 6.88	277,468	$3,571,593	$12.87	546,621	$5,422,877	$ 9.92

[1/] Includes small amount sold for seed inoculant.
[2/] Includes small amount sold for earthworm culture.

C. Marketing

1. Transportation

a. Characteristics

Transportation is an important factor in the movement of peat throughout the country because its costs, as previously mentioned, represent a major share of the final price of the product. Therefore, because most of the states (excepting those in the Southwest) have local reserves of peat which supply their nearby markets, the distance over which peat can be successfully marketed is limited.

Sphagnum, as a light-weight, fibrous moss, can be dried to about 30 per cent moisture content, but upon being exposed to moisture, it readily reabsorbs water until it is again saturated. When stockpiling, sphagnum moss peat piles must be kept small to avoid spontaneous combustion and decomposition of the peat. Therefore, it must be protected from the elements during transport as well. It has an advantage over reed-sedge peat in that it can be compressed into bales (compression ratio of about 2 or 2-1/2 to 1). Therefore, the utilization of transport equipment by volume is 2 to 2-1/2 times the end application. Stated differently the weight volume or weight value relationships are far better for sphagnum than for reed-sedge.

b. Transportation Cost Models

In order to use a common yardstick for the comparison of transportation costs from production point to market city, the approximate maximum load for a 41 ft. 6 in. standard boxcar is the unit used for applying rail rates. The standard boxcar will hold approximately 40,000 lb of baled sphagnum peat, or 70,000 lb of bulk or bagged reed-sedge peat. Therefore, the rates on sphagnum peat are for a 40,000-lb carload and the rates on reed-sedge peat are for a 70,000-lb carload.

For truck movements, the procedure is to load to the visual capacity and no minimum weight is required. Truck transportation of peat is exempt from economic regulation when moving in interstate commerce. Therefore, the rate need not be published. As a result, the rates given are estimates provided by truck brokers. These approximate rates are assumed to be a reasonable indication of the truck rates between the production points and the markets. Trucks are only available (because peat is a low-value commodity) when truckers are looking for a backhaul in order to return to their points of origin fully loaded. However, few origins have these trucks available; therefore, most of the movements are by rail.

Because sphagnum is sold on a volume basis and reed-sedge is sold by weight, freight rates must be converted to a common unit of measure so that transportation costs can be properly compared. The unit of common comparison is a cubic foot of loose peat because the application of one loose cu. ft. of sphagnum peat is equivalent to one loose cu. ft. of reed-sedge peat. Moreover, 100 lb of sphagnum yields 15 cubic feet of application or 3-3/4 times that of 100 lb of reed-sedge which yields only 4 cubic feet of application.

Rail transportation cost per hundredweight (cwt) from the five representative production points in the United States and Canada to the seven selected market cities are shown in Table 12. However, the cwt rates do not reflect the actual competitive transportation costs of the two types of peat from the five production points. Therefore, Table 13 shows a comparison of the same transportation costs converted to a cost per loose cubic foot basis.

Comparing the two products on a loose cubic foot basis, it is evident that for a given mileage cost compressed sphagnum peat can be shipped over a 3-3/4 times greater distance than the heavier weight reed-sedge peat (i.e., from Duluth to Los Angeles and Phoenix as against Capac to Chicago). This explains why the Canadian sphagnum peat successfully competes, virtually on a national basis, with domestic reed-sedge peat.

Table 14 shows those production points with the lowest transportation cost per cubic foot of loose peat to the selected market cities. These selected markets are shown graphically on Map 1, page 20. The Minnesota producers have a favorable transportation cost to Minneapolis/St. Paul, Chicago, Kansas City and New Orleans and are on an equal basis with New Westminster, B.C. to Phoenix, Arizona.

However, it should be remembered that there are producers located closer to many of these markets such as:

Market City	Location of Closer Reed-Sedge Producers
Phoenix, Arizona	Kremling, Colorado and Bethel Island, California
Chicago, Illinois	Morrison, Illinois and Otterbein, Indiana
Kansas City, Missouri	Morrison, Illinois and Lake Mills, Iowa
Los Angeles	Banning and Bethel Island, California
Philadelphia	Newton, New Jersey and see also 1/
New Orleans	1/

1/ Imported European sphagnum peat at the respective ports.

Table 12

Rail Transportation Costs for Peat from Representative Production Points to Selected Market Cities

(rates in cents per cwt)

Market City	Representative Production Point				
	Duluth, Minn. [1]	Capac, Mich. [2]	Bucksport, Maine [1]	New Westminster, B.C. [1]	Riviere du Loup, Que. [1]
Chicago	55.5¢	35.5¢[3]	102.0¢	130.0¢	98.0¢
Kansas City	64.5	71.5	n.a.	129.0	n.a.
Los Angeles	129.0	129.0	n.a.	129.0[4]	n.a.
Mpls. - St. Paul	32.0	70.0	n.a.	129.0	n.a.
New Orleans	98.0	n.a.[5]	n.a.	129.0	144.0
Philadelphia	106.0	57.5	62.7	157.0	82.0
Phoenix	129.0	129.0	n.a.	129.0	n.a.

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[1] Based upon 40,000 lb maximum load of sphagnum peat.

[2] Based upon 70,000 lb maximum load of reed-sedge peat.

[3] Non-regulated truck rate quoted @ 30¢ is lower cost.

[4] Non-regulated truck rate quoted @ 110¢ is lower cost.

[5] Non-regulated truck rate quoted @ 80¢ is lower cost. Only rail rate available is class rate.

Table 13

Rail Transportation Costs for Peat from Representative Production Points to Selected Market Cities with Rates from Table 12 Converted to a Cents per Cubic Foot Basis

(100 lbs. reed-sedge = 4 cu. ft., 100 lbs. sphagnum = 15 cu. ft.; underscored figures represent low-cost supplier)

	Representative Production Point				
Market City	Duluth, Minn. 1/	Capac, Mich. 2/	Bucksport, Maine 1/	New Westminster, B.C. 1/	Riviere du Loup, Que. 1/
Chicago	3.7¢	8.9¢ 3/	6.8¢	8.7¢	6.5¢
Kansas City	4.3	17.9	n.a.	8.6	n.a.
Los Angeles	8.6	32.3	n.a.	8.6 4/	n.a.
Mpls.-St. Paul	2.1	17.5	n.a.	8.6	n.a.
New Orleans	6.5	n.a. 5/	n.a.	8.6	9.6
Philadelphia	7.1	14.4	4.2	10.5	5.5
Phoenix	8.6	32.3	n.a.	8.6	n.a.

1/ Based upon 40,000 lb. maximum load of sphagnum peat.
2/ Based upon 70,000 lb. maximum load of reed-sedge peat.
3/ Non-regulated truck rate quoted @ 7.5¢ is lower cost.
4/ Non-regulated truck rate quoted @ 7.3¢ is lower cost.
5/ Non-regulated truck rate quoted @ 20.0¢ is lower cost.

Table 14

Summary of Production Points with Lowest Rate to Market Centers
(rates in cents per loose cubic foot)

Market Center	Production Point with Lowest Rate	Rate/Loose Cubic Foot	Mode of Transportation
Philadelphia	Bucksport, Maine	4.2¢	Rail
Chicago	Duluth, Minnesota	3.7	Rail
Kansas City	Duluth, Minnesota	4.3	Rail
New Orleans	Duluth, Minnesota	6.5	Rail
Mpls. - St. Paul	Duluth, Minnesota	2.1	Rail
Phoenix	New Westminster, B.C. Duluth, Minnesota	8.6 8.6	Rail Rail
Los Angeles	New Westminster, B.C.	7.3	Truck

Michigan peat, which accounts for 44 per cent of the total domestic production, is reported as being exported to 16 other states. In fact, 75 per cent of all Michigan peat is consumed outside the state. Despite the transportation cost picture described above, transport costs alone do not appear to limit the market reach for producers; they admittedly influence the area which can be profitably reached. Minnesota producers do and will enjoy transport cost advantages to the markets shown in Table 14 and Map 1, except for local competition where it exists.

c. Movement by Great Lakes into Eastern Markets

The use of the Great Lakes for transporting peat into Eastern markets does not appear promising. There are few ships which leave the Duluth-Superior harbor with available cargo space. In fact, they generally leave with a load of iron ore or grain. The value and size of the demand for peat would not support the movement of a ship or barge unless the peat were used as return cargo for what would otherwise be an empty return movement. Of even greater significance, the Great Lakes shipping season does not start until the major peat shipping season is almost completed.

d. Rail-Barge Movement

Barge movement likewise suffers, though to a lesser degree, from some of the same seasonal limitations that Great Lakes shipments do. On the other hand, there are some barges leaving the Minneapolis-St. Paul terminals empty for southern destinations suggesting a return haul opportunity to peat producers. Several barge officials showed interest in the movement of peat into New Orleans and St. Louis. Furthermore, it is possible to move peat during the spring or summer and store it in an open field for packaging at a break-bulk center.

However, costs via all-rail direct from Minnesota origins to both St. Louis and New Orleans are shown to be significantly less than the rail-barge combination (difference of 7.3¢/cwt to St. Louis and 5.4¢/cwt to New Orleans). A compilation of approximate transportation costs for movement of bulk peat from Minnesota origins to St. Louis and New Orleans is shown in Table 15.

A comparison of barge versus rail rates was made for peat in bales or bags. However, unloading costs are quoted at 40¢/cwt in St. Louis and 35¢/cwt in New Orleans, therefore reducing the possibility of moving peat in bags or bales by way of rail-barge into these areas.

Unless substantial downward rate adjustments for handling and transportation can be negotiated, and this does not look promising, it appears that southward movement of peat via a rail-barge combination is not economically feasible for either packaged or bulk peat.

e. Bulk Rail Movements

Railroads quote the same rates for bulk movements as they do for shipments of packaged reed-sedge. Therefore, there is no cost

Table 15

Costs for Bulk Movement of Reed-Sedge Peat from Minnesota to St. Louis and New Orleans Utilizing Rail-Barge Transportation

(rates in $ per cwt)

From	To	Mode of Transportation	Rate/ cwt	Loading & Unloading Cost	Total Costs/ Move
Duluth	Minneapolis	Rail[1]	$.199	$.038	
Mpls.	St. Louis	Barge[2]	.276	.125	
	TOTAL MOVEMENT	Rail-Barge	$.475	$.163	$.638
Duluth	St. Louis	Rail[1]	$.565	--	.565
	Transportation Savings Using All Rail to St. Louis				$.073
Duluth	Minneapolis	Rail[1]	$.199	$.038	
Mpls.	New Orleans	Barge[2]	.487	.225	
	TOTAL MOVEMENT	Rail-Barge[2]	$.686	$.263	$.949
Duluth	New Orleans	Rail[1]	$.895	--	.895
	Transportation Savings Using All Rail to New Orleans				$.054

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[1] Min. wt. 60,000 lbs.
[2] Min. wt. 600 tons.

advantage of bulk over packaged shipments. Sphagnum cannot be economically shipped in bulk by rail as pointed out previously because there is no means of compressing it.

However, bulk rail movement might offer possibilities for reed-sedge if multiple cars could be moved at any one time. Preliminary investigation indicates that some railroads would be agreeable to a 10-12 per cent reduction in rates for five-car movements. At a minimum weight of 70,000 lb per car, this would require approximately 350,000 lb. Very large volume customers or distribution warehousing in the market would be required to take advantage of these economies. For a distribution warehouse to make this system attractive, the storage costs would have to be less than the volume rate savings, an objective not likely to be attained.

On the other hand, multiple car bulk movements of reed-sedge peat to a high-volume customer would indicate substantial usage. If peat were applied at the rate of about 13,500 lb (20 cubic yards) per acre, 350,000 lb would cover about 26 acres. Research indicates that there is a market potential of such customers where the value of the crop is at least $2,500 per acre and the soil is dry and has a high alkaline content. These soils are found in Arizona, New Mexico and Texas. In these states there are large cooperatives who could furnish the unloading and storage facilities for their own members. Experiments are presently underway to determine the usefulness of this large scale application of peat.

f. Piggyback Possibilities

Piggybacking (TOFC) of packaged peat would provide a producer with the benefit of the low-cost rail movement and the consignee with the flexibility of truck delivery. A major complaint against rail movement is that it forces customers to take delivery in very large quantities. Likewise, customers too small for carload purchases could very well become direct producer customers, thereby saving the "middleman" profit.

Some empty piggyback trailers are moving out of the Duluth/Superior area. This situation could generate favorable rates for bagged or baled peat from northeast Minnesota. Recently, a TOFC rate was filed on peat from southern Minnesota to St. Louis, Missouri at an increase of 11 per cent over the boxcar rate. The 11 per cent investment when coupled with a charge for partial unloading would result in a lesser cost than the boxcar rate plus local delivery of the less-than-carload quantity.

Hence, with the evidenced interest of the Minnesota railroads to provide piggyback service at reasonable cost and the opportunity this service provides directly to the less-than-carload customer and those not having rail service at their warehouse, store or greenhouse, its utilization will definitely expand the total market reach of the Minnesota producer.

g. Trucking

In contrast to imported and Minnesota sphagnum, which moves primarily by rail (except West Coast), the movement of domestic peat is primarily by truck. Actually those producers who have been able to achieve reasonably good distribution for their products have been located in areas having a permanent movement of trucks requiring a backhaul. This is typically the case on the West Coast where trucks move large volumes of produce.

It has been estimated that well over 50 per cent of the Michigan peat is hauled by truckers needing a backhaul. The cost of this trucking is reportedly 25 per cent less than any other mode of transportation.

For most receivers the truck haul has two important advantages: a) a lesser quantity is needed than for the rail car and b) the truck can reach most destinations directly without incurring the costly transfer from rail to delivery truck.

Conversely, where the backhaul truck is not available and the distance over which the haul required exceeds 200 miles to 250 miles, the revenue needed by a commercially operated truck (common carrier) is likely to equal or exceed that of the combined rail and delivery truck costs. For still larger distances the all-rail or TOFC services will normally be the lowest cost method.

At the present time the balance of truck traffic to and from northeast Minnesota is favorable for the movement of peat to major markets in Minnesota, Iowa, Nebraska, Kansas and Missouri. However, the permanence of such movements cannot be predicted. As soon as industrial products are available for the backhaul the low-cost offer of a trucker would naturally disappear.

While a competent business mind will always attempt to utilize the lowest cost method available at the time it is needed, a lasting system for a product of as low a value as peat should be based on rail service and TOFC service where a haul from a railhead to a warehouse is involved.

At the prevailing rail rates there is no doubt that properly promoted Minnesota peat can, in fact, reach large sized markets. The occasional availability of lesser cost backhaul truck volume would merely add some icing to the cake.

2. Distribution and Marketing Organization

Peat is sold through a conventional marketing or distribution structure. Each producer has one or more persons acting in a sales capacity. These people work with and through brokers or manufacturers' representatives in their contacts with buying offices of chains, distributors and large professional users. They will frequently work (missionary selling) with distributors' sales forces in making calls on the retail outlets and to bulk users, such as golf courses, nurseries, school systems, and converters (packagers) -- see Chart 2.

In recent years distributors have been hurt because producers have bypassed this link in the marketing chain. To overcome this bypassing, many distributors have developed their own private labels for marketing exclusively in their trade area. Therefore a proliferation of private labels exists which individually do not generate enough revenue to support any advertising. As a result peat is sold on price alone. There is no brand loyalty in the eyes of the retailer or consumer. However, private labels permit one producer to have more than one distributor in a given market and provide each distributor with an exclusive label.

Private labels are dominant in chain stores. Safeway Stores, The Great Atlantic and Pacific Tea Company, and others have their peat requirements packed on the basis of open bids. Frequently, more than one producer supplies a single chain.

Although new packaging techniques have improved peat marketing, nearly anyone with a small amount of capital and access to a peat deposit can package peat and compete, at least in the local market. This, of course, further depresses basic selling prices of peat. As the transportation cost represents a major portion of the cost to a buyer, local producers virtually dominate their respective areas in bulk peat sales. These local producers sell directly to nearly anyone they can service.

There has been one notable exception to this distribution pattern. The Michigan Peat Company has sold its "Bacto" Michigan peat label exclusively to distributors for a premium price. They have advertised both in "shelter magazines"1/ and on a local basis. The "Bacto" label enjoys the greatest national distribution and sales of any brand.

The greatest volume of packaged domestic peat moves through chain store outlets. As mentioned, it is sold directly to the chains through their central buying offices by sales representatives of the various producers. The use of brokers and manufacturers' representatives is limited to areas furthest removed from the plant location. Traditionally producers shipped directly to chain store warehouses. However, recently major chains have been reluctant to warehouse packaged domestic peat. This has led to "drop-ship" requirements and a consequently higher transportation cost factor.

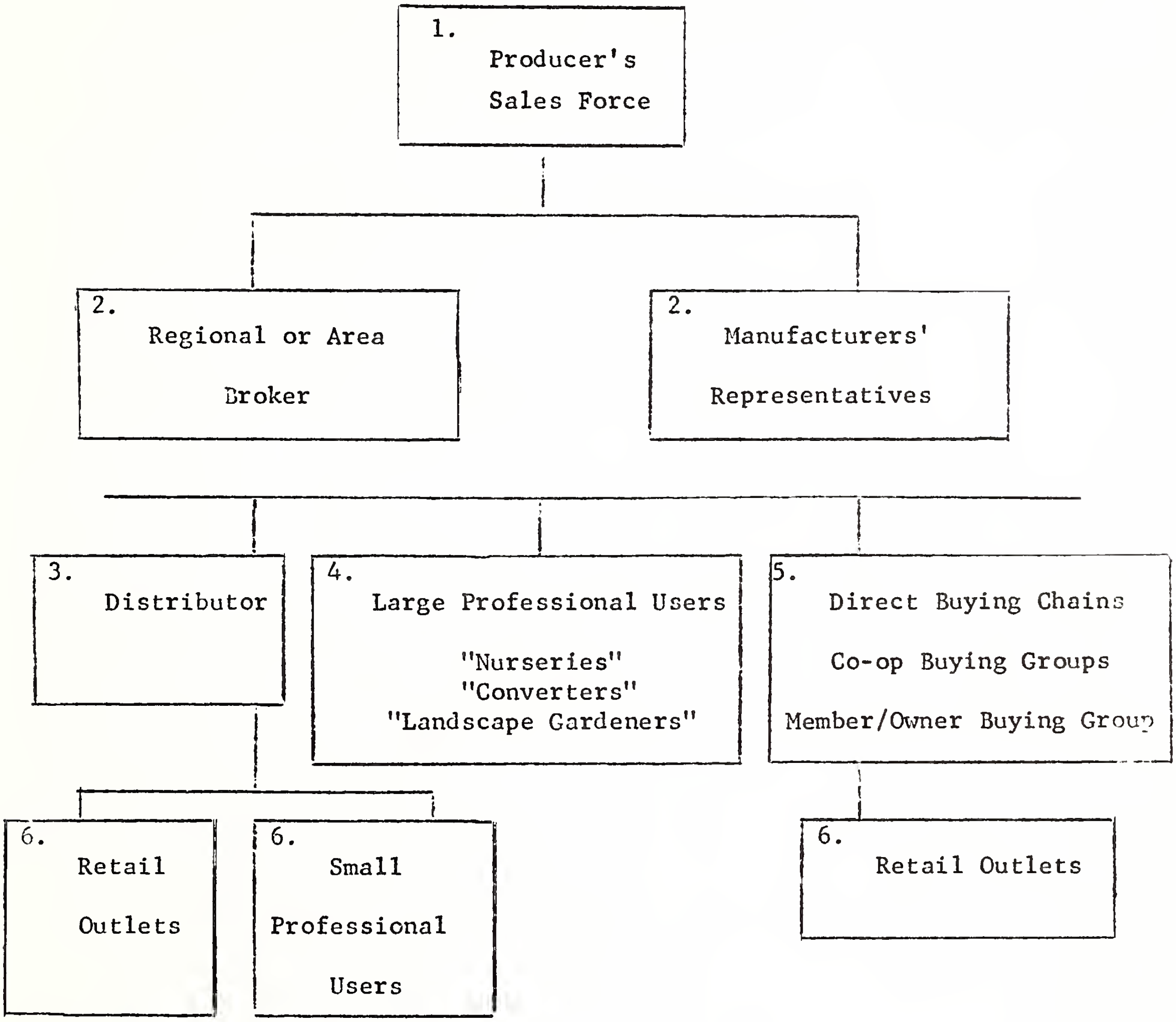
The typical physical distribution of peat is shown in Chart 3.

1/ Trade publications of nursery and gardening retailers.

Chart 2

Marketing Organization Chart

Typical of Major Peat Producers - Domestic and Foreign


1. Producer's Sales Force
2. Regional or Area Broker
2. Manufacturers' Representatives
3. Distributor
4. Large Professional Users
"Nurseries"
"Converters"
"Landscape Gardeners"
5. Direct Buying Chains
Co-op Buying Groups
Member/Owner Buying Group
6. Retail Outlets
6. Small Professional Users
6. Retail Outlets

Functional Description is on the next page.

Functional Description of Chart 2:

1. Producer's sales force implements and directs activity of brokers and/or manufacturers' representatives.

2. Brokers and/or manufacturers' representatives are responsible for sales on a regional or area basis -- theirs is a sales responsibility only.

3. Distributors buy for their own account for purposes of resale to retail outlets or to small professional user accounts.

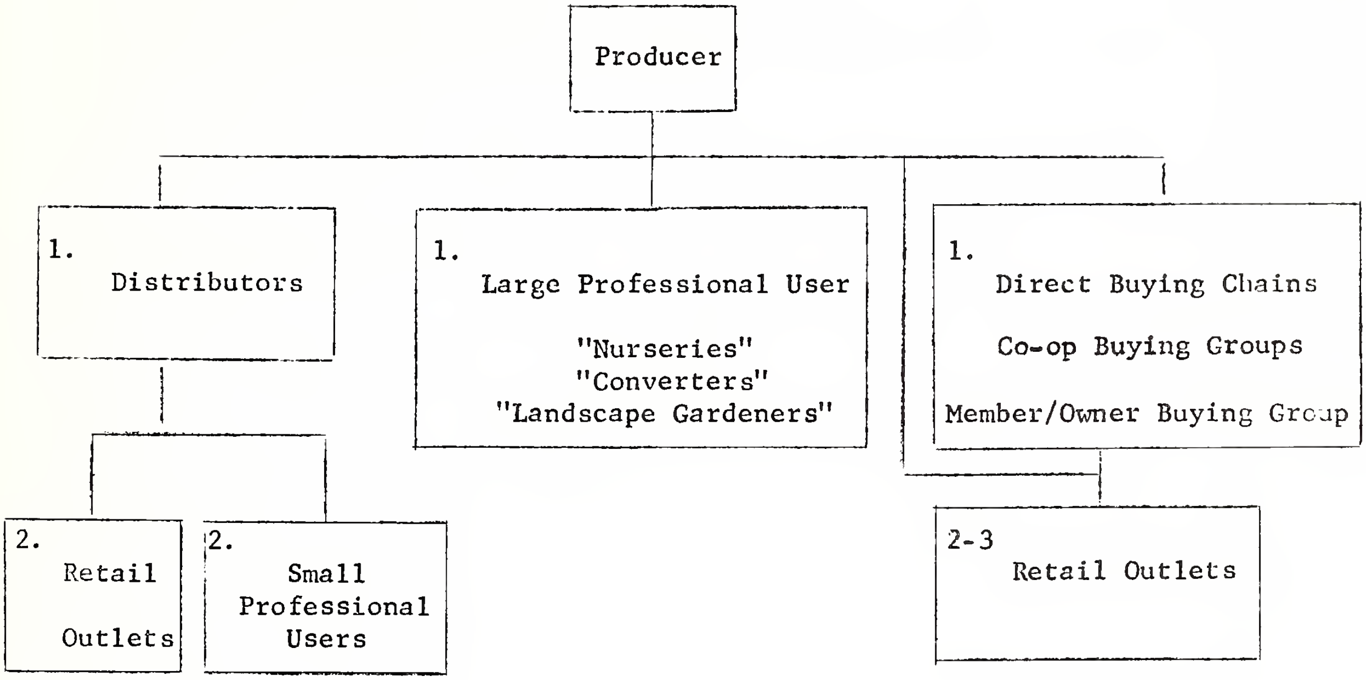
4. Large professional users buy through brokers or manufacturers' representatives in truckload, carload, or multi-units of either for their own use.

5. Direct buying chains, cooperative buying groups and member/owner buying groups buy through singular buying offices for the benefit of their wholly-owned stores or, in the case of buying groups, their member stores.

6. Retail outlets are the final members of the marketing chain making the distribution of the product to the consumer complete.

Chart 3

Typical U. S. Peat Distribution Pattern


Producer
1. Distributors
1. Large Professional User "Nurseries" "Converters" "Landscape Gardeners"
1. Direct Buying Chains Co-op Buying Groups Member/Owner Buying Group
2. Retail Outlets
2. Small Professional Users
2-3 Retail Outlets

Functional Description:

1. Product moves via rail or truck to warehouses of:
    a. Distributors
    b. Large Professional Users
    c. Direct Buying Chains, etc.
2. Product moves via truck from the warehouses of 1 above to:
    a. Retail Outlets
    b. Small Professional Users
3. Certain exceptions to this pattern occur when product moves, via truck, from the producer directly to a retail outlet on a drop shipment basis.

3. Advertising and Promotion, Present and Future

Over the years there have been sporadic and ineffective attempts to advertise peat in its various forms. Advertising has often been sponsored by individual producers in selected areas without continuity or an effective theme.

There are good reasons for this. Peat has been sold as a commodity rather than a consumer item. As a commodity there was not sufficient margin to permit effective advertising. With the advent of attractive consumer point of sale packaging, the industry cut prices and reduced margins rather than maintain a structure capable of producing advertising dollars.

The European producers first dominated the market. Their burlap-baled product was not attractive; yet, they sold what they produced without advertising or promotional support. Since World War II, the Canadian industry has become the major peat exporter to the U. S. Because of the intense competition between the U. S., Canadian and European producers, the margins were not adequate to support large advertising budgets. However, producers have done some magazine and cooperative advertising with nurseries and distributors. Cooperative advertising programs reportedly include the supply of mats and from 25 per cent to 75 per cent of the cost of local retailer advertising depending on the quantity of peat purchased by the retailer; i.e., 100, 500, 1,000 bag (or bale) quantities. Advertising (space) costs in three of the leading magazines directed to the garden retailers and their respective circulations are as follows:

	Circulation		1-Page Rates		
Publication*	Retailers	Wholesalers	1	6	12
Lawn/Garden/Outdoor Living	31,252	1,947	$630	$570	$510
Modern Garden Center	25,867	2,993	560	495	425
Home and Garden Supply Merchandiser	25,586	1,566	570	515	460

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* Source: Standard Rate and Data Service, Inc., Skokie, Illinois.

The average cost for a one-page advertisement in 12 consecutive issues is $465 per ad or $5,580 for the twelve. Assuming a producer was willing to allocate as much as 2¢ per bale toward medium advertising, to recoup the expense for the 12 ads would require the sale of 279,000 bales or 12,357.5 tons of sphagnum -- obviously a very considerable quantity for any of the existing producers, excepting the two or three largest ones. Conversely, the suggestion that a larger share of the sales dollar be allocated to advertising and promotion is only sensible when doing so will result in a net profit at the increased volume.

The example demonstrated by the Michigan Peat Company is vital. It has promoted -- admittedly at considerable cost -- an identifiable product which only it can supply. Over the years consistently reliable quality, good packaging and reliable deliveries have enabled this company to obtain the premium price which in turn has supported an advertising cost which may be as high as 10 per cent of gross revenue.

Minnesota, it is recommended, should follow a similar path. The effective promotion of its sphagnum peat resources can be undertaken if it is stressed that the 85-lb weight of the 6-cubic foot compressed bale contains 3 to 3-3/4 times the product contained in a 100-lb reed-sedge bag. The slogan, "a little more than twice the price for 3 to 4 times the value," backed up by an easily understood explanatory statement, is likely to produce the desired results when put before the retail consumer on a continuing basis. Admittedly, such a program does require a substantial amount of "seed money" -- an investment in creating brand loyalty to stimulate the sale at a profitable price. But again, because sphagnum in view of its lighter weight per "unit of coverage" enjoys such an important transportation cost advantage, it is doubly significant to stress the true properties of a bale's contents. Hence, sphagnum transportation savings do not need to be passed on to the consumer through disproportionately lower prices. If an advertising campaign costing as much as $1 million (including interest on the cost of the money) can result in the sale of only 5 million bales of Minnesota sphagnum (212,500 tons) over 3 to 4 years and at a price which is only 20¢ higher than current prices, this cost of promotion would be fully absorbed by incremental revenue while the price is still only 74 per cent of the "value" compared with reed-sedge peat.[1/]

There is no doubt that sales in the order of magnitude projected can be generated. Population growth and per capita consumption growth support that projection. An effective advertising and promotional campaign should result in consumption gains more closely approximating those which have been experienced in recent years in lawn and garden fertilizers, weed killers and other soil additives such as lime. National statistics for these products seem to average about a 10 per cent annual growth. In those markets favorable to Minnesota sphagnum production, a 10 per cent annual growth rate could result from a well-planned and adequately financed sales effort. Preferably the conscientious development of this market for a Minnesota-brand sphagnum should be undertaken as a joint enterprise of state -- the land or deposit owner -- and the producer(s). Considerations of public policy relative to land use, employment generation, maintenance of product standards in terms of quality, quantity and supply reliability amply justify the state's involvement and investment in the development of this virtually virgin industry in the State of Minnesota.

[1/] Based on calculation: sphagnum price $3.99 plus 20¢ = $4.19 for, say, 13.5 loose cubic feet = 31¢/cu ft versus reed-sedge price of $1.69 for 4 cu ft = 42¢/cu ft; 31 ÷ 42 = .737 or, say, 74 per cent.

IV. Appendix

A. Brokers (Importers)

Typical brokers who are prominent importers from Europe and Canada include:

The J & M Trading Co., Chicago, Illinois

The Ezl Dunwoody Co., Philadelphia, Pennsylvania

Premier Peat Moss Co., New York City, New York

The Transphere Trading Company, New Orleans, Louisiana

Meyer & Co., San Francisco, California

E. J. Long Co., New York, New York

The Half Moon Trading Co., New York, New York

B. Distributors

Typical distributors include:

Wetzell Feed and Seed Co., Harrisonburg, Virginia

Cottongin Company, Atlanta, Georgia

H. G. Hastings Company, Atlanta, Georgia

Everett Seed Company, Atlanta, Georgia

Stegall Sylvest Company, Montgomery, Alabama

Norala Seed Company, Birmingham, Alabama

E. K. Hardison Seed Co., Nashville, Tennessee

Ferd Staffel Company, San Antonio, Texas

Binding Stevens Company, Tulsa, Oklahoma

Tobin Seed Company, Kansas City, Missouri

Bartels & Shores Chemical Company, Kansas City, Missouri

American Excelsior Corp., Minneapolis, Minnesota

Gould Seed Company, St. Paul, Minnesota

C. Industry Regulations

The marketing of peat is regulated under "Trade Practice Rules" promulgated January 13, 1950, by the Federal Trade Commission.

Under these rules product definitions are spelled out. Minimum label requirements are developed and certain voluntary disclosures of package contents are recommended.

Rule A is of particular consequence, even though it is only recommendatory.

"The industry recommends that because peat products have high moisture absorbing qualities, such products be sold by industry members on a dry measure basis (bushels, cubic feet, cubic yards, etc.), rather than by weight; provided, that such recommendation shall not be construed as disapproval by the industry of the practice of selling industry products by weight when in immediate conjunction with the stated weight the dry measurement is also shown."

This recommendation has not been followed by the majority of producers. Producers frequently call peat simply "Sphagnum Peat Moss" or just "Peat Moss".

The Peat Producers' Association of the United States, headquartered in Washington, D. C., has as its basic purpose the establishment of equitable trade practices under the jurisdiction of the FTC. It is contemplated that existing trade practice rules will be modified to accommodate changes in the industry.

Dr. Rouse Farnham, Organic Soils Specialist of the University of Minnesota and an honorary consulting member of the Peat Producers Association of the United States, in his paper, "A Statement on Standardization of Commercial Peats," states:

"To insure high quality commercial peat, uniform standards for the various kinds of peat should be established. Regulations governing standards and trade practices for the peat industry established in 1950 should be revised so that quality control of the product is possible. This is desirable both from the standpoint of the customer as well as the seller or producer. From the standpoint of the buyer it is important that he be assured of receiving the kind and quality of peat stated on the bag label. From the standpoint of the producer, regulations governing trade practices and quality control are necessary to protect him from incorrectly labelled and/or inferior products which are on the market in competition with him.

"Standardization involves a consideration of the various kinds of peat and the important properties which affect the quality of the commercial product when used. The physical and chemical properties most important are water-absorbing capacity, ash content, acidity, (Lime Content), and volume weight.

"In the interest of both the producer and consumer of peat, there is need for improvement in some of the Federal Trade Commission Provisions. To protect consumers and to regulate the quality of peat produced by the industry, the per cent of organic matter present in a bag of commercial peat should be stated on the bag in much the same manner as the per cent of nitrogen, phosphate and potash is listed on a bag of commercial fertilizer."

(Due to the natural high organic, low ash content of northern Minnesota peats in general, any new regulations requiring more detailed description or declaration of organic matter would work to the advantage of peat producers located in this area. -- Editor's note.)

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